THE ROAD TO EXTINCTION

A SYMPOSIUM HELD BY THE

SPECIES SURVIVAL COMMISSION

Madrid, 7 and 9 November, 1984

Edited by RICHARD AND MAISIE FITTER

THE ROAD TO EXTINCTION

Problems of Categorizing the Status of Taxa Threatened with Extinction

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Convener	Sir Peter Scott	Chairman Emeritus, SSC
Speakers	Michael J. Bean, USA	Environmental Defense Fund, Washington, DC
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	Dr F. Wayne King, USA	Director, Florida State Museum, University of Florida, Gainesville
	Dr V. Sokolov, USA	Director, A.N. Sevetzov Institute of Evolutionary Morphology and Animal Ecology, Moscow
Other Authors	William K. de la Mare, UK	International Institute for Environment and Development, London
	Richard Fitter, UK	Chairman, Fauna and Flora Preservation Society, London
	Professor V.H. Heywood, UK	Botany Department, University of Reading
	Dr Paul Munton, UK	IUCN/WWF
	Reed F. Noss, USA	School of Forest Resources and Conservation, University of Florida, Gainesville
	Dr Laurence Roche, UK	Department of Forestry and Wood Science, University College of North Wales, Bangor
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OBJECTIVE OF THE SYMPOSIUM

Well over 150 Red Data Books (RDBs) for both animal and plant species have appeared so far. Many of these descend directly from the first IUCN/SSC Red Data Book for Mammals, published in 1966, which itself was preceded by various lists of extinct or vanishing species or species in need of protection, some published many years before. These RDBs all classify species under such headings as 'endangered', 'threatened' and 'vulnerable', without necessarily defining these terms in the same way, or at all. In addition, certain legislation, especially in North America, uses RDB categories and terminology to describe circumstances in which certain actions are either mandatory or prohibited. Although the endangered species concept has a *prima facie* appeal, and has been an effective central theme of the conservation movement, the simple terminology associated with it obscures the complexity of the extinction processes and is often used wrongly or ambiguously in public policy. This Symposium seeks to analyse and synthesise the fundamental principles and points of view involved, so as to make the concept a more effective conservation tool.

PROCEEDINGS

The Chairman first introduced the members of the Panel, explaining that they would comment on the prepared papers before contributions were invited from the floor. He then invited the Convener, Sir Peter Scott, prime mover in the development of IUCN's Red Data Book series, to give some personal observations.

Sir Peter Scott emphasised the need for sustained conservation action, with studies over a much longer time-scale than most present research. He added that although we never seem to do exactly the right thing, we can at least try to do the least wrong. He then outlined the role of the SSC, under the successive leadership of Hal Coolidge, Leofric Boyle, himself and now Gren Lucas, in initiating and developing IUCN's Red Data Book series. To start with there were just lists of large animals and an emphasis on extinction, a simple and absolute idea much easier for public opinion to grasp than the complexities of ecology and genetics. It was a long time before ecological and genetic thinking led the SSC to tackle small animals and plants. He felt strongly that for limited funds to be made an excuse for allowing even obscure and little known species to become extinct was morally wrong. If man himself were listed as endangered, this might bring home the danger to mankind of thoughtlessly destroying so much of the world's natural resources, leading to an acceleration in the extinction of species all over the world, but especially in tropical rainforests.

The Convener called on his co-author, John Burton, to present their joint contribution to the Symposium.

RED DATA BOOKS: THE HISTORICAL BACKGROUND

Sir Peter Scott, John A. Burton and Richard Fitter

Introduction

Although it is generally known that the senior author originated the Red Data Book concept in 1963 and that the first two volumes were published in 1966, their precise history is poorly documented and largely unknown, even to professional workers in the field.

The main precursors of the Red Data Books were three publications of the American Committee for International Wildlife Protection (ACIWP), whose founder in 1936 and first chairman was John C. Phillips, after whom IUCN's principal award of merit is named. The first, *Extinct and Vanishing Mammals of the Western Hemisphere* by G.M. Allen, was published in 1942, followed by Francis Harper's *Extinct and Vanishing Mammals of the Old World* (1945) and J.C. Greenway's *Extinct and Vanishing Birds of the World* (1958). By this time IUCN's Survival Service Commission (SSC) had been set up. Greenway and Harold J. Coolidge (who died in 1985) provided important links between ACIWP and SSC, for Coolidge signed the foreword to Harper's book on behalf of ACIWP. The influence of ACIWP on the early SSC was clearly substantial.

However, even before the ACIWP publications, there had been a handful of works which might be regarded as ancestral to the RDBs. They are included among the more than 150 RDBs and threatened plant lists catalogued by Jarvis *et al* (1981), and the 154 similar titles for animals listed by Burton (1984); a few more have come to light since. The most notable of the early animal titles are William T. Hornaday's *Our Vanishing Wildlife* (1913) and three papers in the *Journal of the Society for the Preservation of the Fauna of the Empire*, the precursor of *Oryx*, journal of the Fauna and Flora Preservation Society (Anon 1928, Dollman 1937, Johnson 1937).

A true Red Data Book could probably be defined as a register of threatened wildlife that includes definitions of degrees of threat. Hornaday's book appears to be the earliest with a claim to be a national RDB (for the United States of America) and has been overlooked by virtually all subsequent writers, including Allen for ACIWP. A notable feature of many of the earlier works is the use of the term 'vanishing'. Eric Johnson's 'List of Vanishing Gambian Mammals (1937) has a better claim to be the first true national RDB, while G. Dollman's 'Mammals which have recently become extinct and those on the verge of extinction' (1937) might serve as the proto-RDB for the mammals of the world.

Dollman's paper and an anonymous SPFE paper, 'Notes on animals which have become totally extinct through human agency during the nineteenth century' (1928), provide a link with the earlier tendency to list and discuss extinct species only, which included such well known books as J.E. Harting's *British Animals Extinct within Historic Times* (1880) and W.H. Hudson's *Lost British Birds* (1894).

We are grateful to A.J. Mence (1981 and *in litt.*) for the following summary of the early history of the SSC as it relates to the RDBs: Coolidge presented a paper, 'Emergency action for the preservation of vanishing species', to the International Technical Conference on the Protection of Nature at Lake Success, N.Y., in 1949. This conference was organised jointly by Unesco and the International Union for the Protection of Nature (IUPN), as IUCN was called until 1956, and was the first of IUCN's series of Technical Meetings. Coolidge pursued a suggestion he had made at the 13th North American Wildlife Conference in 1948, and recommended the setting up of an 'International Survival Office' within the IUPN framework, to co-ordinate information on vanishing species. The Conference duly passed a resolution (no. 15) that IUPN should set up a 'Survival Service', for 'the assembling, evaluation and dissemination of information on, and the study of, all species of fauna and flora that appear to be threatened with extinction, in order to assist governments and appropriate agencies in assuring their survival'.

IUPN soon appointed Coolidge as Chairman of the Survival Service, and in May 1950 J.M. Vrydagh of the International Office for the Protection of Nature (the pre-war forerunner of IUPN) was asked to organise it. At IUPN's Second General Assembly at Brussels in October 1950 Vrydagh reported that Colonel Hoier of IUPN had started to update the Harper/Allen mammal records on a card index; this was later maintained by J-J. Petter in Paris. He added that he did not have the resources to do much about plants. Coolidge appointed an unofficial commission of eleven zoologists and botanists to assist him. The first meeting of the Survival Service lasted only two hours.

The Lake Success meeting had drawn up a list of 14 mammals and 13 birds in need of action 'if they are to be saved from extinction'. Like most of the early listings, they were large, well known animals, some of them only subspecies or local populations, and one, the Marianas mallard *Anas x oustaleti*, now considered to be a hybrid. This list was reviewed 25 years later by Fitter (1974). At the first meeting of the Survival Service in 1950, suggestions to add species to this list were referred to a sub-committee. However, when IUPN published the next major listing as *Les Fossiles de Demain* in 1954, it was the same as before, apart from the omission of two species of monk seal, and was indeed republished unchanged in 1958. At the Third General Assembly, at Caracas, Venezuela, in 1952, the Survival Service formally handed over the task of maintaining the records for threatened birds to ICBP. In 1956, at the Fifth General Assembly at Edinburgh, Scotland, the Survival Service became a full Commission (SSC). At the next General Assembly at Athens, Greece in 1958, Harold Coolidge handed the chair over to Lt. Col. C.L. Boyle, Hon. Secretary of the Fauna Preservation Society.

By 1958 Coolidge was able to report that the list of threatened mammal taxa stood at 26. This small increase is somewhat surprising since the original Lake Success resolution called for the Union to maintain 'an open list' of rare and threatened animal species. Moreover, when Fitter (1974) reviewed the fate of the species in the first list of threatened mammals and birds, drawn up a quarter of a century before, he found that the direct intervention of the SSC had materially affected only two of these and that governmental bodies had been mainly responsible for the efforts to save most of the rest.

The basic lists continued to expand slowly under the new SSC/FPS regime, and the status of many threatened species was documented in the FPS journal *Oryx*, culminating in 1960 in a long and detailed report on threatened mammals in Asia by a young Californian ecologist, Lee Merriam Talbot, grandson of the distinguished American zoologist Charles S. Merriam. This report, 'A Look at Threatened Species', was a joint production of ACIWP, who funded the research along with two private donors, and FPS, who published it in *Oryx* with a foreword by Coolidge, by then an IUCN Vice-President.

In 1960, Boyle reported to the Warsaw General Assembly that the SSC had established a small secretariat in London and started a card index of data on the 34 species of mammals now considered threatened. This index, detailed in an appendix to the SSC's report, also takes its place in the evolution of the Red Data Books. A further 25 mammals plus an unspecified number of lemurs, were also listed for consideration by the SSC. Boyle had also organised distribution maps for a number of species, a feature yet to be included by IUCN in any of its published Red Data Books. At the same Warsaw meeting J.H. Calaby and F.N. Ratcliffe presented a documented list of Australia's threatened mammals and ICBP reported on the original 13 birds, plus Steller's albatross *Diomedea albatrus*, which had been added in 1958, and made suggestions for adding three more.

By 1963 the SSC was moving with increasing momentum towards the first real Red Data Book. Its Chairman's report to the Eighth General Assembly at Nairobi, Kenya, proposed a complete reorganisation of the Commission, with a small membership based on 'groups of the Animal and Vegetable Kingdoms and not geography'. This was agreed, together with a new 'Classification of Endangered Forms', which is discussed by Munton.

To coincide with the Ninth General Assembly at Lucerne, Switzerland, in 1966, both the mammal and bird volumes were published in loose-leaf 'specialist editions', with the intention of keeping them up to date by the issue of new or replacement sheets. The fact that these original loose-leaf volumes were specifically intended for specialists has often been ignored. Two years later the third loose-leaf volume, for Reptiles and Amphibians, appeared under the editorship of René E. Honegger of the Zurich Zoo. Next came Vol. 5 Angiosperms (Flowering Plants), compiled by Dr. Robert Melville of the Royal Botanic Gardens, Kew, in 1970. This was the first Red Data Book to recognise frankly that with some groups, notably plants and invertebrates, so many species are rare or threatened, and so little is known about most of them, that the full treatment accorded to mammals and birds is never likely to be possible. Last of the old-style RDBs was Vol. 4 on Freshwater Fishes, by Professor Robert Rush Miller of the University of Michigan, which did not appear until 1977.

Meantime, IUCN took an important step by sponsoring the publication in 1969 of the popular version of the first RDBs under the title *The Red Book: wildlife in danger*. Its authors were James Fisher, the distinguished British naturalist and SSC member, Noel Simon and Jack Vincent, and it remains IUCN's only attempt to popularise the mass of data accumulated by the RDB operation. The bulk of the book was devoted to mammals and birds, with short sections on reptiles, amphibians, fishes and plants, but nothing yet on invertebrates. Harold Coolidge once more provided the foreword, jointly with the senior author.

By the mid to late 1970s there was widespread discussion about the future development of the Red Data Books, partly due to the confusion over the various editions and periodic additions to the loose-leaf volumes. The three original volumes appeared in revised loose-leaf editions: Mammals, edited by Colin Holloway and Harry Goodwin, in 1972; Birds, by Warren King in two volumes in 1978 and 1979; and Amphibia and Reptilia, by René Honegger in 1979. At this point, early in 1978, the *Red Book* went out of print. At the same time came the first of the bound volumes, The IUCN Plant Red Data Book, compiled by Gren Lucas and Hugh Synge, followed by a bound version of the revised Bird RDB, published by ICBP in 1981.

But the decisive step towards the present situation was taken by IUCN and SSC in 1976, when they appointed Jane Thornback as compiler of the Mammal RDB. Though she at first harked back to the beginning by working out of the Fauna Preservation Society's London office, she soon moved to Cambridge to form the nucleus of the Species Conservation Monitoring Unit, which, along with the Threatened Plants Unit at Kew, became in 1983 a major part of IUCN's Conservation Monitoring Centre at Cambridge. The first fruits of the new regime appeared in 1982: *The IUCN Mammal Red Data Book. Part 1. Threatened Mammalian Taxa of the Americas and the Australasian zoogeographic region (excluding Cetacea)*, compiled by Jane Thornback and Martin Jenkins, an indication that so much data had now been amassed that it could no longer be accommodated in one volume. It was followed by volumes on Amphibia and Reptilia (Part 1, Testudines, Crocodylia, Rhynchocephalia), by Brian Groombridge and Lissie Wright, also in 1982; Invertebrates, by Susan M. Wells, Robert M. Pyle and N. Mark Collins, in 1983; and *Threatened Birds of Africa and Related Islands*, by N.J. Collar and S.N. Stuart, in 1985. Other volumes are in preparation.

By the mid-1970s national RDBs were also beginning to appear, with more and more countries producing their own RDBs and similar listings of threatened and endangered species. The Red Data Book for the USSR, edited by one of the SSC's Vice-Chairmen, Andrei Bannikov, was published for the IUCN General Assembly at Ashkhabad, Turkmenistan, in 1978.

Road to Extinction

The development of RDBs has now reached a particularly interesting stage, where they could evolve along several possible lines. The existing RDBs already represent different approaches, and are increasingly becoming the biological equivalent of the Forth Bridge, where repainting has to start at one end as soon as it is finished at the other. This was one of the problems the loose-leaf version was intended to solve, but it is also a problem that modern technology can solve more easily, with the computer at CMC.

Another problem is that of the popular version. It is more than 15 years since the 'Red Data Book' was published, and the public desperately needs another, for the 'new generation' RDBs, excellent as they are, tend to fall between two stools. On the one hand they are too detailed and technical for anyone but a specialist, who, however, is best served by direct access to the database (computer records); on the other hand, students, amateur naturalists, journalists and other well informed members of the general public each have their own distinct needs. Their demands, coupled with the needs of lobbyists, administrators and decision-makers involved in wildlife legislation, are the challenge of the future. A significant development is the rapidly increasing extent of the database held by the CMC, which now includes records of taxa threatened regionally or nationally as well as those threatened globally, to which IUCN's Red Data Books have hitherto been confined.

It is perhaps worth considering how much the data published in Red Data Books influences listings in legislation, as opposed to mere listing in a RDB. In the case of amendments to CITES, the data is vital, but in the original CITES listings and many national legal instruments concerning wildlife, decisions often appear to have been based on a listing alone, without regard to the supporting data. A more comprehensive review of this might influence the approach to the RDBs of the future.

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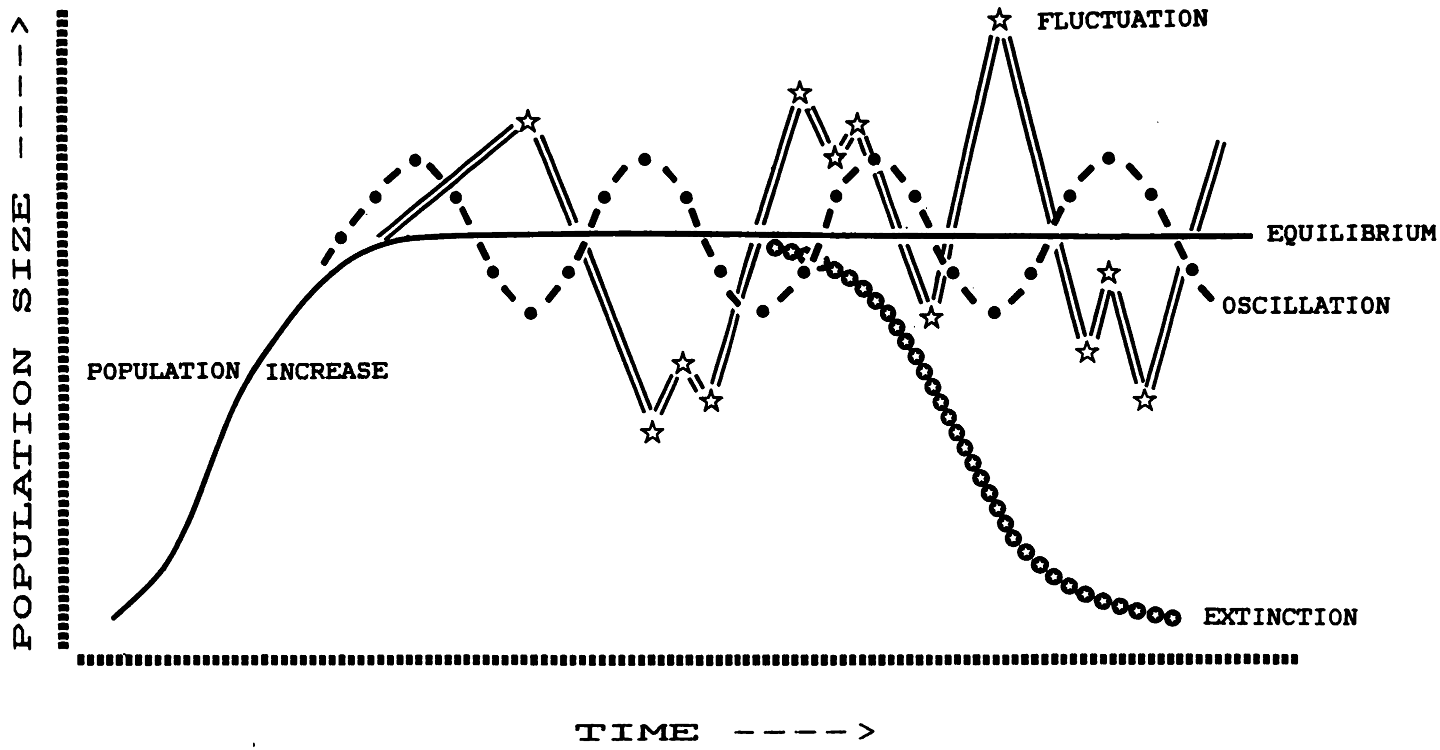


Figure 1. Stylized representations of population states (adapted from Allee, Emerson, Park, Park, and Schmidt 1949). Few, if any, populations are so stable as to be in equilibrium (solid line). Most exhibit fairly regular seasonal or annual oscillations (broken line and dots) or undergo irregular fluctuations (double line and stars) that reflect changes in predators, prey, food, habitat, or other limiting factors. If mortality consistently exceeds reproductive success, extinction (enclosed stars) is inevitable.

THIRTEEN MILESTONES ON THE ROAD TO EXTINCTION

F. Wayne King

Over the last century, much attention has been focused on species being driven to extinction by man, but remarkably few attempts have been made to categorize the imminence of extinction in a way that would allow species to be grouped together by degree of threat (see Paul Munton's paper, Chapter 9.). The first such categories to be widely used were those in the IUCN/SSC Red Data Book (RDB), most of which have been incorporated in various forms into international, national, and local law. But these are not entirely satisfactory. Several are subjective, and most are not based on biological characteristics. For example, the 1969 RDB 'endangered' category, on which all others depend, was defined as:

'In immediate danger of extinction: continued survival unlikely without implementation of special protection measures.'

Since this was one of the first published uses of the term, it was appropriate to explain that 'endangered' means 'immediate danger of extinction'. The wording also indicates that these are not simply biologically rare taxa with stable populations; they need active assistance if they are to survive.

In 1972, the RDB categories were revised slightly, and some criteria stated. For example, the Mammal RDB (IUCN 1972) defines endangered as:

'Taxa in danger of extinction and whose survival is unlikely if the causal factors continue operating. Included are those taxa whose numbers have been reduced to a critical level or whose habitats have been so drastically reduced that they are deemed to be in immediate danger of extinction...'

Reduction in numbers, loss of habitat, and the immediate threat of extinction are all characteristics of some endangered species, but they do not cover all endangered taxa.

In 1971, the IUCN/SSC Crocodile Specialist Group (CSG) attempted to draft a definition of 'endangered' (Bustard, 1971) which has a strict biological basis:

'A species is endangered when its numbers are consistently being depleted more rapidly than they can reproduce themselves. Absolute numbers may not be relevant to its threatened status since large populations can be reduced catastrophically by adverse factors.'

This is remarkably similar to Ziswiler's (1967) definition of extermination:

'A species becomes extinct when its mortality is continually greater than its recruitment. If a particular population loses more animals than it gains through reproduction, total extermination becomes a simple matter of time.'

A population can be monitored to determine if its death rate exceeds its birth rate; if it does so consistently, the population will grow smaller and smaller until the last member dies. But both these definitions have two serious shortcomings. They do not reflect any imminence of extinction; a population of 10,000,000 individuals could be eradicated in a year, or its death rate could exceed its birth rate by one individual a year and thereby survive 10,000,000 years. Nor do they cover populations that are stable or those increasing in numbers but endangered by a pending catastrophe, such as a terrestrial species confined to a single river valley which becomes endangered as soon as work begins on a dam that will flood the valley, even though the reservoir has not yet begun to fill.

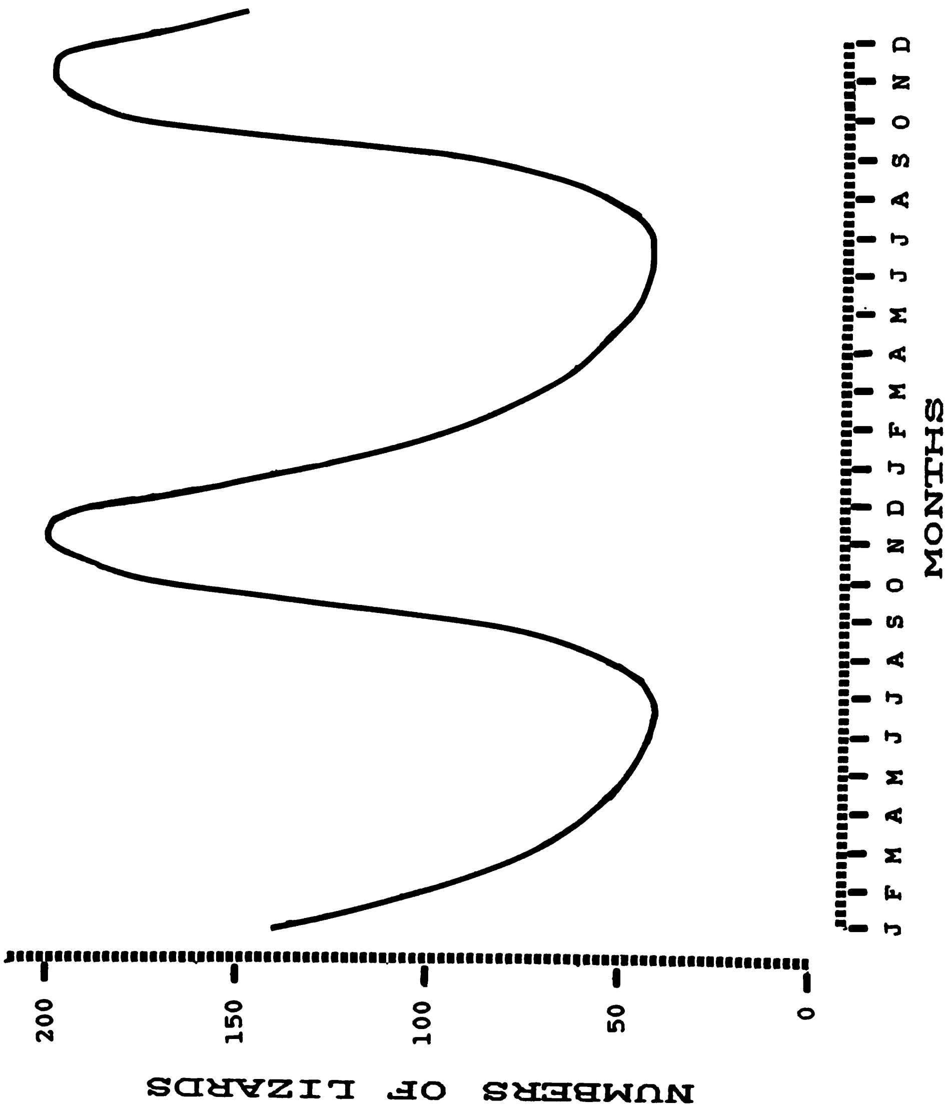


Figure 2. An April to December reproductive season combined with the loss of over 95% of the population each year produces annual oscillations (approximated here) in bark anole, *Anolis distichus*, populations in south Florida, U.S.A.

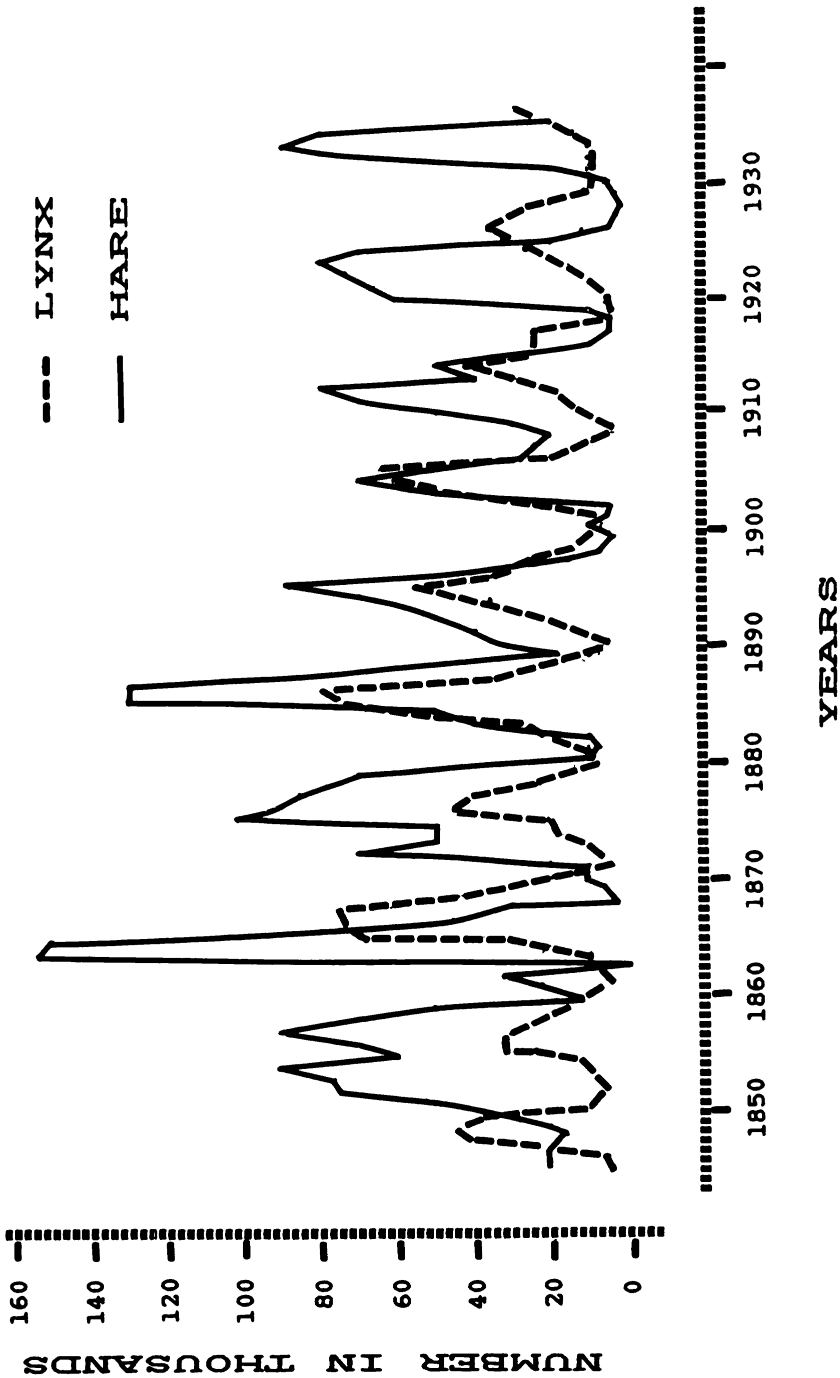


Figure 3. Correlated fluctuation of predator, *Lynx canadensis*, and prey, *Lepus americanus*, populations in Canada (redrawn from MacLulich 1937).

It might be possible to redefine the various RDB categories so that all taxa can be easily assigned to the proper grouping, stable, declining, rare, endangered, or extinct, with a minimum of dispute. That can only be done if the categories take into account the milestones - characteristics of biological populations and taxa - on the way to extinction. Several recent studies have identified some characteristics of extinction-prone species and populations, and the factors that threaten them (Diamond 1984; Soulé 1983; Terborgh and Winter 1980). Species and populations seem more apt to become extinct if the individual longevity or generation time is short; if the carrying capacity (K) or population size is small; if the species is rare; if the population's intrinsic rate of increase (r) is low; if the ratio of birth rate to death rate is low; if the populations do not vary in size; if the species has a limited distribution (including island species and those isolated by man); if the species faces heavy competition, predation, or habitat alienation; of if the species is dependent on another species that is being lost.

THE MILESTONES

1. **Discovery and Scientific Description of the Species.** The first milestone in determining the status of any species, or other taxon, is knowing that it exists. If it is not known to exist, obviously its extinction also will be unknown. Yet failure to understand this very obvious point is the source of much recent criticism aimed at conservationists. A species becomes known to science when it is discovered and then described in the scientific literature by a systematic biologist. The most diverse assemblages of species on earth, the vast majority of which have yet to be discovered and described, occur in tropical rainforests, where the rate of deforestation is such that many biologists have independently projected that millions of species, possibly twenty per cent of all species alive today, will become extinct in the next twenty to thirty years, and even at the present time at least a species a day is being lost. (Ehrlich and Ehrlich 1981; Lovejoy 1980; Myers 1979; Myers 1984; National Research Council 1980). Yet since most of the species have not been described, it is impossible to demonstrate that they are becoming extinct, which has prompted some disbelievers to claim that extinctions are not occurring and will not occur. Incongruous though it may seem, the first milestone on the road to extinction is the discovery and subsequent scientific description of the species.

2. **Continuous decrease in numbers.** Few, if any, populations are stable over the short term; their numbers change depending on the availability of food and habitat, on reproductive success, numbers of predators and a variety of other factors -- see Figures 1-3. If the death rate consistently exceeds the birth rate, a species or population is in decline and will eventually become extinct unless the trend is reversed -- See Figs. 1 and 4. Periodically censusing the population will reveal long-term trends, whether numbers are increasing, decreasing, or stable. However, unless ecological studies accompany the censuses, it might not be possible to determine why a particular trend is occurring. A long-term continuous decrease in numbers is a milestone on the road to extinction, and many other causes are discussed below as milestones.

3. **Habitat loss.** Habitat loss is the single greatest cause of endangerment and extinction of wild species. Wild species are captives of the particular environments that satisfy their ecological and behavioral needs. When a natural habitat is destroyed, the many species that are dependent on it and unable to migrate to another satisfactory habitat also disappear, unless man artificially provides those needs in captivity in botanic gardens, zoos, or farms. Habitat destruction takes many forms, e.g., deforestation, desertification, pollution, soil erosion, siltation. Timber cutting endangers the entire monarch butterfly *Danaus plexippus* population of eastern North America in the Mexican forest habitat where it overwinters. Similarly, conversion of their rainforest habitats to oil palm plantations endangers both the Sumatran rhinoceros in Malaysia and Queen Alexandra's birdwing butterfly *Ornithoptera alexandrae* in Papua New Guinea. Fragmentation of habitat seems to force the extinction of rare species, including large predators, and their loss in turn produces a secondary series of extinctions - Milestone 11 (Terborgh & Winter 1980). Significant habitat loss is a major milestone on the road to extinction. If as a result of habitat loss a species is reduced to only a small fraction of its former range, it surely is threatened and may be on the verge of extinction.

4. **Significant fragmentation of range or contraction of distribution.** The geographical distribution of many threatened species has shrunk so drastically that they survive only in one or a few fragments of their former ranges. This could result from losing major portions of its former habitat (Milestone 3), or it could reflect extirpation of some populations from existing habitat (Milestone 5) or some other adverse factor (Fig. 5). Species that start with a severely limited distribution, such as those endemic to oceanic islands, desert springs, or oases, are particularly susceptible to endangerment and extinction.

5. **Over-exploitation and crash.** Populations of many commercially valuable species decline rapidly after being exploited at levels that exceed their reproductive potential. (Fig. 5, 6 and 7). Even superabundant species can become extinct in a few years if exploitation is excessive; commercial exploitation of the passenger pigeon *Ectopistes migratorius* reduced its numbers from billions in 1810 to around 200 million in 1870, and finally to one captive female only 40 years later (King 1978). On the other hand, large harvests are not necessarily a sign of over exploitation; more than 10 million waterfowl are killed by North American sport hunters in a regulated annual harvest, but with few exceptions this does not exceed the reproductive success of the species. Monitoring the numbers of plants or animals collected or killed will show whether the exploitation rate for a given population exceeds the reproduction rate. If it does, and the hunting effort remains unchanged, the offtake will decline. If the hunters move into new areas, go farther and farther afield to get the same number of specimens, or use more efficient methods, there may be a time lag before the reported offtake declines (King 1981). Records of the exploitation rate of a wild species are a major milestone on the road to extinction if they indicate the population is crashing.

6. **Profound reduction in reproductive success.** Some species become threatened when reproduction ceases or is greatly curtailed, e.g. when the adults of many slow-maturing species are exploited preferentially; when breeding habitat is lost; when individuals become so scattered that reproduction becomes improbable. Sea turtles require from 10 to 40 years to reach sexual maturity, so removal of breeding adults rapidly depletes a population, which takes decades to recover its former numbers. For olive ridley sea turtle *Lepidochelys olivacea* arribadas, the massive aggregations of nesting females, on the Pacific coast of Mexico have collapsed as a result of excessive exploitation (Ross 1981). The Devil's Hole pupfish *Cyprinodon diabolis* in Nevada, USA, all but ceased to breed when pumping for irrigation lowered the water level below a rock shelf on which the fish spawned. A sustained, significant reduction in reproductive success is a significant milestone on the road to extinction.

7. **Curtailment of seasonal cycles.** Some threatened species no longer exhibit crucial seasonal behavior, e.g., migrations no longer take place; breeding aggregations no longer occur. Impoundments, siltation, pollution, and other environmental perturbations have disrupted the return migrations of many anadromous fishes, e.g., Atlantic salmon *Salmo salar*. Tens of thousands of red hartebeest *Alcelaphus caama* migrating to water have died on the veterinary fences erected across Botswana in an ill-planned attempt to control rinderpest and hoof-and-mouth disease. If the fences remain in place, the population will crash and the migration be lost. The lost of characteristic seasonal cycles may be another significant milestone on the road to extinction.

8. **Excessive competition from introduced species.** Introduced exotic species are often such aggressive competitors that they may occupy all available habitat, nesting sites and basking sites, usurp food sources, and inhibit reproduction or growth of native species, thereby threatening their survival. Oceanic islands often serve as refuges for plants and animals that cannot withstand much competition, and have disappeared on the mainland under pressure from aggressive competitors. When competitors are introduced to those island refugia the native species suffer; introduced mongooses, goats, rabbits, and cats have exterminated many island species and endangered many others. Rats, goats, pigs and donkeys are major threats to the survival of Galapagos giant tortoises *Geochelone elephantopus*. Feral cats and dogs have destroyed populations of Galapagos land iguanas *Conolophus subcristatus* and Turks and Caicos land iguanas *Cyclura carinata*.

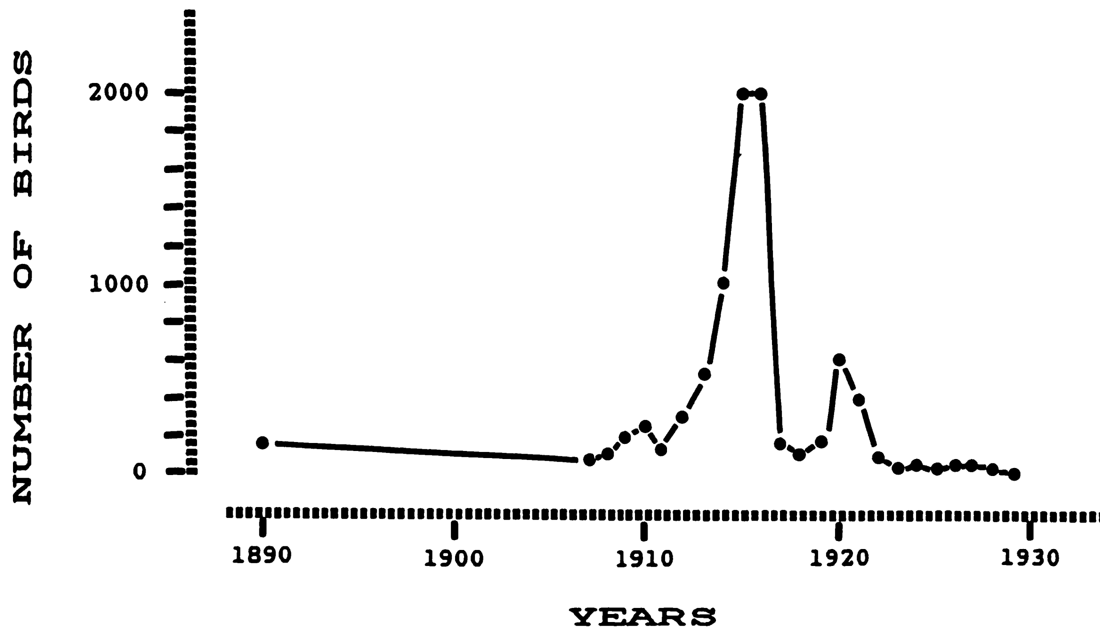
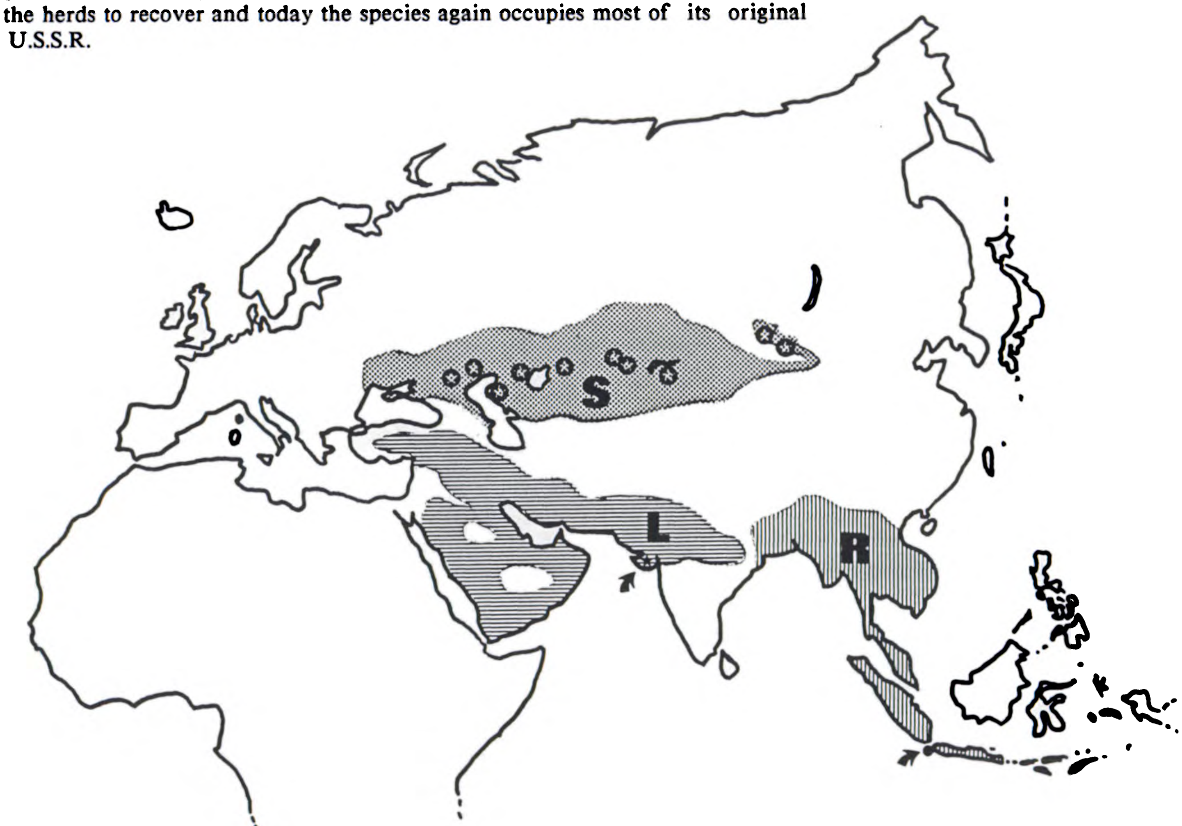


Figure 4. The decline, temporary recovery, and extinction of the heath hen, *Tympanuchus cupido cupido*, on Martha's Vineyard, Massachusetts, U.S.A. (redrawn from Gross 1928).

Figure 5. Fragmentation and contraction of the ranges of the (L) Asian lion, *Panthera leo persica*, (R) Javan rhinoceros, *Rhinoceros sondaicus*, and (S) saiga antelope, *Saiga tatarica* (adapted from Bannikov 1961; Talbot 1960). Original distributions of the species are shaded or cross-hatched. The remnant wild population of the Asian lion in Gir National Park, India, is indicated by the star and arrow. The only remaining population of the rhinoceros is in Udjong Kulon National Park, Java, Indonesia, indicated by the dot and arrow. By 1920, the saiga had been so decimated that it survived only in the scattered populations shown by the enclosed stars; however, conservation management has allowed the herds to recover and today the species again occupies most of its original range in the U.S.S.R.



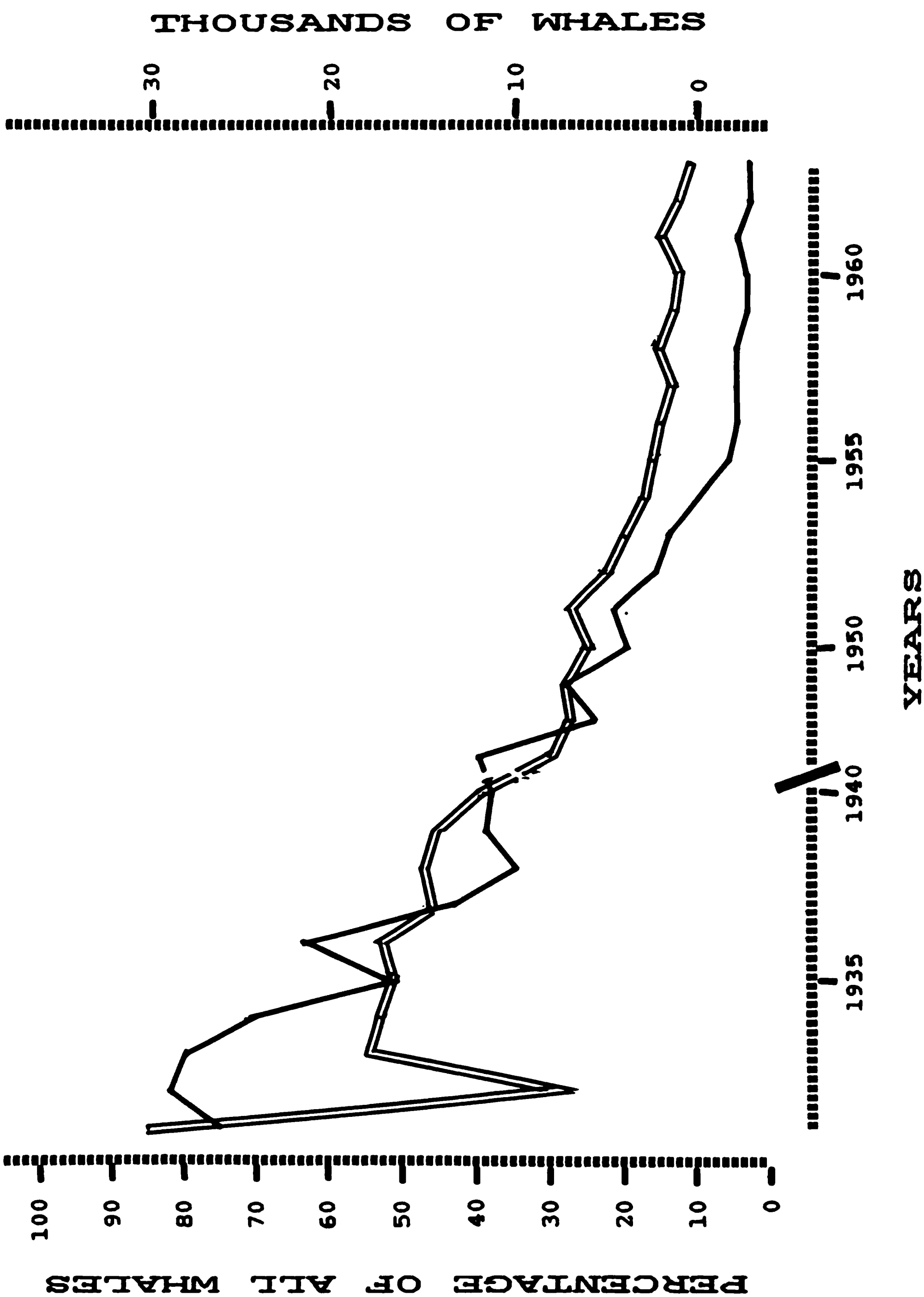


Figure 6. Decline and endangerment of Antarctic blue whale populations, as reflected in both the numbers caught each year (double line) and the percentage (single line) that blue whales represented among all whales killed in that region (redrawn from Ehrenfeld 1970)

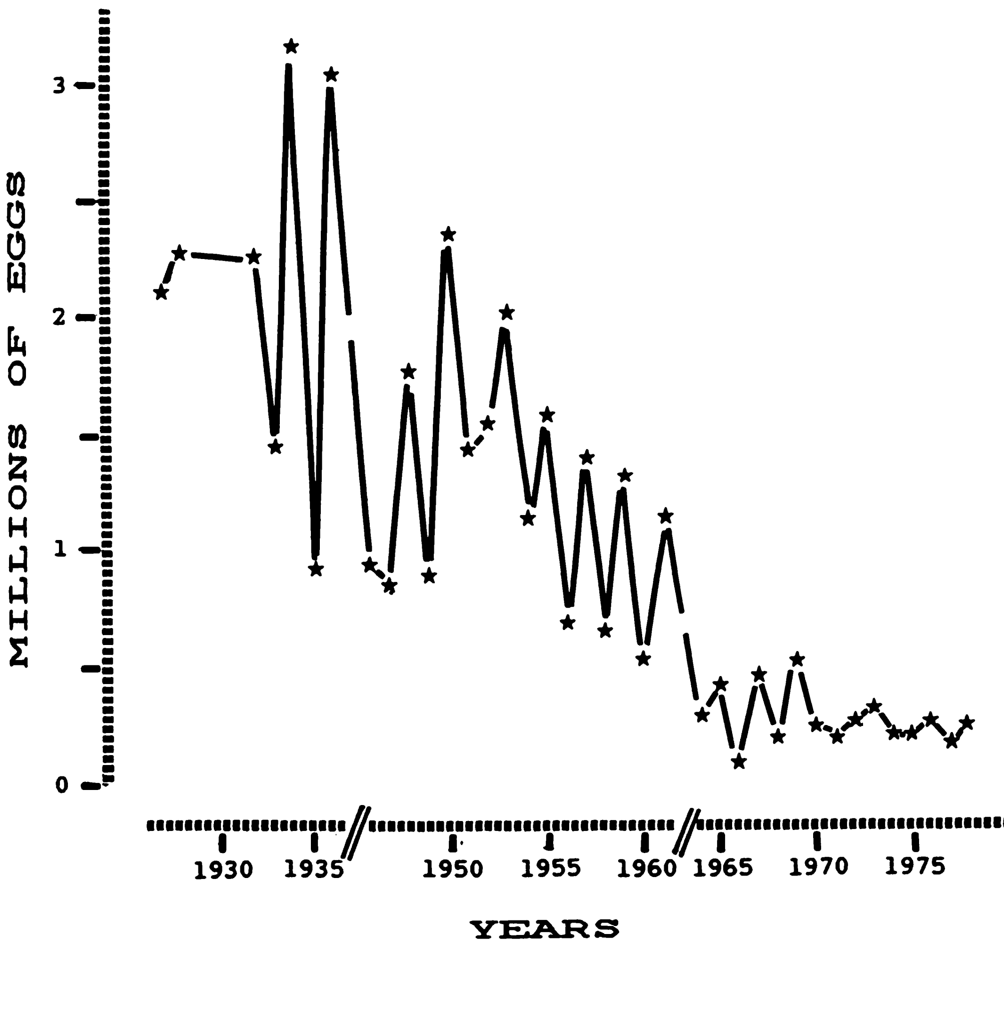


Figure 7. Endangerment of Sarawak, Malaysia, green turtle, *Chelonia mydas*, populations as documented in the number of eggs harvested (redrawn from King 1981).

Introduced crab-eating macaques *Macaca fascicularis* eat the eggs of the endangered kestrel *Falco punctatus* and pink pigeon *Nesoenas mayeri* on Mauritius. The habitat of *Wahlenbergia linifolia*, a low-growing flowering plant endemic to St Helena in the South Atlantic, was first decimated by introduced goats, and now is being overrun by introduced blackberry *Rubus fruticosus* and New Zealand flax *Phormium tenax*. The introduction and explosive spread of exotic competitors frequently serves as a milestone on the road to extinction, especially on island refugia.

9. **Hybridization and genetic swamping.** Introduction of exotic species into the range of related native species, or the breakdown of natural barriers between the ranges of closely related native species, may lead to hybridization, so that one species is genetically swamped by the other. Interbreeding with feral domestic horses contributed to the extinction of the Mongolian wild horse *Equus przewalskii*. Similarly, the presence of feral domestic Bactrian camels and yaks threatens the survival of their wild relatives in Asia.

10. **Pending catastrophes.** Some species may appear to be as abundant as they ever were, but are threatened by some pending catastrophe, e.g., species in a particular river valley flooded by a dam built downstream; when deforestation on mountain slopes causes soil erosion and siltation; when pollution begins from a new industry; or from volcanic eruptions. An estimated sixty per cent of the world's unionid clam fauna occurred in the streams and rivers of North America, but eighty to ninety per cent have become endangered or extinct because of siltation behind flood-control dams (King 1978), a catastrophe that was predictable once the dams slowed down the current and the water dropped its sediment load. Construction of an oil-bunkering port near Lagunas de Chiriqui, Panama, represents a pollution catastrophe waiting to happen to the surrounding coral reef and estuary species. Pending catastrophes may be among the hardest milestones to identify on the road to extinction.

11. **Extinction of co-evolved mutualistic species.** The loss of one species often produces a cascade effect that brings about the extinction of other dependent species (King 1984; Terborgh & Winter 1980). The extinction of an obligate host means the end of its parasites as well. The destruction of a particular tree species will force a change in the populations of animals that feed on its fruit. The loss of each rainforest tree species probably carries with it the extinction of ten or more invertebrates and microorganisms (Raven 1981). Conversely, many plants are dependent on their animal pollinators, e.g., the primary pollinator of the durian tree *Durio zibethicus* in south-east Asia is a species of nectar-feeding bat that is threatened because some of its limestone roosting caves are being mined away for cement. The disappearance of almost any large vertebrate results in the loss of a specific dung beetle. In rainforests and other complex ecosystems with intermeshed layers of mutualism, a milestone on the road to extinction of any species in a co-evolved association is the endangerment or extinction of the species on which it depends.

12.**Commercial extinction.** Over-exploitation has made some species so scarce that it is no longer profitable to search them out. The trade then often switches to other less desirable species. In the mid-1960s, when crocodile hides became increasingly scarce and hard to procure, the international reptile leather industry turned to sea-turtle hides as a substitute (King 1978). Such commercial exploitation of alternative sympatric or syntopic species can subsidize the continued exploitation of the depleted species. When the more valuable black caiman *Melanosuchus niger* became too scarce in Amazonia for hunters to continue making a living from its skins, they turned their guns and harpoons on the less desirable common caiman *Caiman crocodilus*, and the money thus earned allowed them to stay afield and kill the occasional black caiman they stumbled across. The same thing happened with many other species; the whaling industry has turned to smaller and smaller cetaceans as the giants became too scarce to sustain the industry. A milestone on the road to extinction has been reached for a commercially exploited species when it becomes so scarce that the exploiting industry continues operating only by turning to a more abundant alternate species, and it is a major milestone if the hunting of the alternate species subsidizes the continued exploitation of the commercially 'extinct' species.

13. Extinction. A species is extinct when the last living speciman dies, but it is often difficult to determine precisely when this has occurred, particularly with secretive species that were always hard to find. But if a species has not been seen in the wild in fifty years, despite efforts to locate it, it may be presumed to be extinct, although it is not unknown for species to be rediscovered after being thought to be extinct for longer than that.

These 13 milestones can be used to help determine which species are endangered, which ones have mortality rates consistently exceeding their reproductive rates, and which populations are declining at a rate indicating imminent extinction. Like their highway counterparts, single milestones (save for the 13th) may indicate only that the trip has begun. The more milestones a species or population has passed, the more certain it is that the final destination - extinction - is drawing near. Conservation management aims first to stop and then to reverse the direction of the journey.

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CATEGORIZATION OF THREATS TO AND STATUS OF WILD POPULATIONS

Sidney J. Holt

This paper attempts to analyse the 'problems' of the original symposium title in the hope of achieving a synthesis, drawing mainly on my experience with marine vertebrates, particularly mammals.

The idea that a species may be on a road to extinction derives from a mode of linear thinking which it is time to discard. If we wish to apply geometric analogies to our perception of the problems of species conservation, we should think of the species as somewhere within a network, a web that should also be envisaged as three-dimensional, and remember that the reality will have more than three dimensions. Then our problem becomes one of predicting into which region of space the species is being driven by human or other agency. From the human point of view, some regions will be less desirable than others. Perceptions of desirability will vary, but it may be possible to agree that certain regions are desirable for us all and others undesirable. The broad agreement that extinction of biological species, other than some parasites and disease organisms, is undesirable is one such consensus.

Deliberate action to move a species towards a more desirable region of its existence 'space', or at least to maintain its position in the face of natural forces, we call 'management'. Thus we try to manage our own behaviour with respect to the species itself and/or to its natural habitat and its general environment. 'Conservation' is a vector of management, by which the species is to be steered away from a particular category of undesirable space.

This symposium is held in the context of IUCN's activities. It is therefore appropriate to focus on the central policy document of the Union - not a Red Data Book, or any other specific tool, but the World Conservation Strategy, and thus ensure that our discussion is relevant to the needs of other organizations directly connected with the Strategy - WWF, UNEP, FAO, Unesco - as well as of governments that have declared their adherence to it in principle, and of other international organizations that are affected by it, such as CITES.

The WCS sets three main objectives. The first two are:

- to maintain essential ecological processes and life-support systems;
- to preserve genetic diversity.

The third I would like to reformulate as:

- to ensure that any utilization of species and ecosystems is sustainable.

(This re-formulation is to remove a possible implication in the original wording that all species and ecosystems *must* be utilized. In fact it is often overlooked that this third objective is specifically directed to those species and ecosystems 'which support millions of rural communities as well as major industries').

Protection of genetic diversity has often been interpreted as if the phrase referred only to the multiplicity of Linnean species. But the ability to adapt to changing conditions, including response to human impact, requires genetic diversity *within* the species, and even within distinct populations of the species. Failure to adapt implies movement in the existence space towards an undesirable condition. Hence conservation involves measures intended to maintain genetic diversity within populations. A particular but very important case is the direct exploitation of wild populations to produce commodities. Almost always this involves, either intentionally or simply implicitly in the exploitation method, a high degree of selectivity, for example by size of animal or by sex. The genetic consequences of this have generally been ignored, being assumed to be small, or very long-term and therefore of no practical concern. Recent studies - mainly theoretical - have indicated that the genetic consequences of selective exploitation will be bigger, and be manifest in a shorter time, than has been supposed. For this and other reasons the second and third WCS objectives must be seen as closely linked.

Virtual extinction is relatively easy to recognise once it has happened. Although it is notoriously difficult to be sure that the last individual of a population has died, straightforward monitoring will usually establish that a species has become so rare that it practically no longer plays any significant role in the ecosystem. We usually feel confident in affirming this even when we are unsure what role it originally played. However, to determine that a species is moving inexorably in the direction of this particular condition is exceptionally difficult; indeed it may be possible to do so with rigour. At the present time it might be possible to say, in a certain situation, that if everything else stays the same a particular human action will increase the probability of extinction within a certain time by a certain amount. Any such prediction would necessarily be based on rather simple and essentially untested mathematical models. It is therefore not satisfactory for conservation tactics to be directed strongly to the prevention of extinction as such. But that result, among others, will be achieved if the species in question is maintained so that it continues to play a significant part in 'essential ecological processes and life-support systems', and, if it is exploited, so that the exploitation is sustainable. So, categorization of its' status will contribute to attainment of all three WCS objectives.

Before proceeding to consider what such a categorization system would involve we need to establish what we mean by 'species'. I suggest it will serve our purpose to adopt the CITES definition; that is, 'any (Linnean) species, subspecies or geographically separate population thereof'. We might add that 'geographical separation' should be taken to include seasonal separation where two or more populations of a Linnean species occupy essentially the same area but use it in differing seasonal patterns.

Our definition means abandoning an assumption that extinction of a 'species' is necessarily and absolutely undesirable. It may not be desirable for long-term human interest, or for the future well-being of the Linnean species, that all its geographically separate populations survive. Our view will depend, among other things, on how many separate populations are known to exist, and the condition of each of them. This simple example shows that the status of a species can only satisfactorily be categorized by explicitly taking account of the status of closely related species. This is true whatever the biological level of definition of the 'species'. If a particular Linnean species is the only known species in its genus, or even in its family, it could be categorized differently than it would be if, say, it were one of many species in the larger taxon.

The CITES criteria or, rather, the so-called 'Berne Criteria' (Resolution 4 of the first meeting of the Conference of Parties, 2-6 November, 1976) also give an important clue to the basis for useful categorization. In this case the act of categorization is the listing of a species on one of three Appendices to the Convention or, by implication, not listing it on any of them. The Resolution says that, in determining the appropriate Appendix into which a species should be placed, the biological and trade status of the taxon should be evaluated together. Thus categorization involves taking simultaneous account of the status of the species itself and in this case, of an identified threat to that biological status - international trade - and the interaction between these. The Berne Criteria also establish that the categorization of one species is affected by the categorization of related species. Thus, in defined circumstances the listing of one Linnean species on Appendix I of CITES means that other species in the genus must be listed on Appendix II unless there is a reason for listing them otherwise.

Generalizing from the CITES approach, in the light of the preceding discussion, I conclude that the status of a species, once defined, can be categorized for conservation purposes only by formulating and evaluating together

- the intrinsic biological status;
- the status of the habitat and general environment;
- the nature of the other external influences, specifically of the direct and indirect 'threats' from human activity;
- the categorization of closely related species.

It may be noted that this fourth requirement implies that in practice categorization is an interactive process.

Why Categorize?

In trying to define the location of a species in its existence space, and the boundaries of less and more desirable regions, we have to deal far more often with continuous variables than with discontinuities. So to establish categories we must make artificial boundaries where natural ones do not exist. Why do this when it would give a better idea of 'location' to specify it by, say, some coherent group of numbers and signs? The answer lies in the uses to which categorization is put. There seem to be three types of use, not all mutually compatible. The first is to convey a perception to the lay public and for this categories need to be few and clearly defined. The second is for the drafting and, eventually, implementation, of laws, regulations, international agreements and the like; categorization is intrinsic to most of these. The third is by professionals in this conservation field, for purposes of programme development and especially for setting 'priorities', when funds and facilities are limited - as they invariably are.

Categorizations forced into linear form force linear thinking by professionals and bureaucrats. Their determination of priorities and subsequent decision-making rest only partly on any index or category assigned to the species in question; they have to take into account such matters as the means available for action, the likelihood of success in a given time-frame, public opinion and other political considerations. It seems to me unlikely that forcing all we know or don't know about a species into a linear strait-jacket is particularly helpful to them in their difficult and often thankless task.

It is in laws and regulations that categorization plays an important role, since the time-honoured practice is to specify entities to which an act does or does not apply, either by definition within a text, or by inclusion in or exclusion from an annexed list which may be amended according to criteria and procedures themselves defined in the text. There is, of course, a direct relation between this process of embodiment in laws and regulations, and categorization for popular consumption. This relation is strongly affected by the nomenclature chosen for the categories, because most of the technical terms used have other and different vernacular meanings. Issues also become confused for other reasons. One is loose use of terms. Something - a species? - is described as 'endangered' - this means some feature of the species is considered likely to disappear, but which? Its very existence? Its actual or potential value as a resource? And what is the time-scale in mind for this change? This is not the place to examine the matter of terminology in depth, but we need to be aware of this problem, if we are not already, and try to find ways of solving it, after we have come to some conclusions about the categorizing process.

In trying to sharpen our thinking about categories I believe we should pay close attention to three features of the problem:

1. When the status of a species has been defined we need to categorize it not in itself but in its relation with both more and less desirable regions. Appropriate categories are relative, not absolute.

2. Where, as is usual, a category boundary is to be established at some chosen value of one or more continuous variables, locations where change is 'smooth' - linear - should be avoided, and preference given to locations where change is inflected or accelerating/decelerating; we should seek pseudo-discontinuities. There are good practical as well as theoretical reasons for doing this. Since there are always considerable uncertainties about the process of categorization, and the result of that process is to be used politically, there will always be pressures to shift category one way or another if the species is judged to be near a boundary. At least the latter can be more easily resisted if there are objective criteria for the boundaries.

3. Some way must be found to incorporate the ideas and knowledge of probability and uncertainty explicitly in the process of assessing the status of a species with a view to categorizing it. Remembering that uncertainties also surround the boundary of undesirable and desirable spaces, there are two approaches to meeting this requirement. One is that the status of the species, as a point in a multi-dimensional space, is regarded as surrounded by an 'atmosphere' of uncertainty - a haze. Then, an envelope containing most of this atmosphere is defined according to some generally acceptable high probability that the true locus is not outside the envelope. The location of status is then redefined as the entire envelope - as a space rather than as a point - and it will be considered to fall in a particular category only if the entire envelope is within the bounds of that category. If the envelope crosses the boundaries between categories some transitional rule will apply. (Note that in a multi-dimensional system an envelope can be intersected by the boundaries of more than one category). For this there are several possibilities. One is that the envelope is considered to be in the category in which its greater part lies. Another is that it is arbitrarily placed in one category or another according to the nature of the risk it is thought opportune to take; so we could have 'conservative' or 'risky' rules. A third possibility is that if a species is judged to lie near the boundary between pre-defined categories it is placed in a new 'special' category to which a modified - perhaps an intermediate - rule will be applied.

The other approach to dealing with uncertainty is to categorize the species according to the best available assessment of its condition, but to adjust the rules to take account of the probabilities of the species being correctly or incorrectly placed in that category. This approach also calls for the formulation of a special decision procedure and/or intermediate rules. It is applicable when the rules permit of quantitative modification, as in setting catch limits for exploited species.

What is Status?

Dictionaries define status as 'the condition of a (person or) thing in the eyes of the law', 'a state of affairs' and 'a position or rank in relation to others'. The idea of 'rank' is strong but not mandatory. I am suggesting here that we view status as a location in a multi-dimensional space relative to other locations defined as desirable or undesirable. The parameters, values of which define this location, may be grouped as:

- intrinsic;
- extrinsic, concerning the status of closely related taxa at the same, higher or lower level;
- extrinsic, concerning the habitat of the species;
- extrinsic, concerning the general environment of the species;
- extrinsic, concerning the array of forces (threats) acting on the species directly or on any and all of the other extrinsic parameters.

The intrinsic group includes statements both about the static qualities of the species and its dynamics. The relevant static qualities are roughly of two kinds: fixed features of the natural history/life cycle of the species, which may determine its vulnerability to certain kinds of forces - its 'reproductive strategy', for example; and numerical measures of population structure, which include population size; age, size and sex compositions; birth and death rates; genetic diversity; and the like.

The dynamic qualities include the rates and directions of change over recent time in the static qualities, and also functions of their dependence on each other, and it is commonly assumed that the most important are those in which population size or density is the independent variable. The externalities of habitat and natural environment also need to be specified both statically and dynamically in terms of directions and rates of change.

Threats

It may be helpful to examine the various classes of threats and then the underlying causes of those threats, the identification of which will surely affect the way in which the perceived threats will be taken into account in specifying the status of a species. One important class of threat in many situations is directed killing of the individual organisms. This usually involves exploitation for products, as in hunting for skins, meat or ivory. Such killing may have different consequences and implications if it is legal or not, and whether it is regulated or not. Direct killing, ostensibly for other purposes, may also constitute a threat. Current examples, from among many, are 'culling', supposedly to protect the interests of those who depend for a living on exploiting the prey of predatory species, or to protect humans from physical danger or damage to property; and 'sampling' for supposedly scientific purposes. These are examples of how a particular threat may be enhanced, perhaps unintentionally, by rules which govern the particular type of 'legal' killing. Thus, it seems to be sensible to require that any 'culling' or 'sampling' of a 'useful' species should be accompanied by full utilization of carcasses, yet that very requirement gives a powerful incentive for increasing the scale and the duration of the killing. Further, it has quite often led to deliberate perversion of the original intentions of provisions for 'culling' or 'sampling'.

A second type of direct - but not directed - killing is 'incidental', as distinguished from 'accidental' killing. The former is that which inevitably occurs as a consequence of some other kind of human activity. A classic example is the killing of dolphins in tuna purse-seines in the tropical Pacific Ocean. These seines are deliberately closed around schools of dolphins so that the tuna swimming underneath also can be gathered. Entanglement of marine mammals, seabirds, turtles and unwanted fishes in fishing nets, which is an increasing problem world-wide, has been called 'accidental'. The distinction between 'accidental' and 'incidental' is a subtle one - perhaps too subtle. It has been remarked that most accidents do not 'happen', they are *caused*. Nevertheless, the distinction may be useful insofar as it may signal the relative ease with which the unwanted deaths may be reduced or even eliminated through technical or operational changes. Thus much of the net entanglement problem could be solved by requiring that old nets should not be discarded at sea; stopping the dolphin kills in tuna nets calls for very substantial changes in the fishing operations.

Directed killing, as well as undirected killing, changes the static properties of the species and, through this, its dynamics. Other kinds of human action could do the same, though their effects may be even harder to measure. A current marine example is the debate about the effects on breeding and other vital behaviours of whale watching close up by numbers of people in boats.

Threats to habitat may also be direct or indirect, and it may be useful from the point of view of categorization to treat these separately. Removal of habitat is a well known phenomenon with respect to terrestrial wildlife, usually involving putting land to other human uses. There are also many ways by which living space of a species is indirectly reduced by human activities. A special case of this might be the introduction of exotic species which compete directly for space with the species under consideration. It may or may not be useful to distinguish between threats to habitat and threats to environment. In the latter class I would include 'pollution' as defined, for example in the Convention on the Law of the Sea: exploitation and other modes of destruction of species constituting the food of the species under consideration. Threats to closely related taxa would be identified in the same ways as threats to the species under consideration and to its habitat and environment.

Road to Extinction

What about the all-important underlying causes of these threats? One, concerning an exploited species, might be replacing subsistence use with catering to a large commercial market, perhaps involving international trade. The very existence of such a market constitutes a threat to the species that can supply it, since the flow of commodities through those markets is not effectively controlled. CITES addresses a specific causative threat of this kind. A second example might be the existence of a virtually unlimited market for meat in wealthy countries. This, directly and indirectly, is imposing threats to wildlife in East Africa and to wildlife in rainforest. The similar unlimited demand for timber is, of course, another causative agent. Local growth of human populations has often been cited as a source of pressures on wildlife. This has frequently been confused with increase in the *presence* of humans in a particular place, caused by their movement from another place. Here the underlying cause of threat is to be sought not in human birth and death rates, but in the causes of the migration pressure.

It would be possible to dig to a deeper level of causation, looking at 'human nature', global population growth, and so on, but this would take us too far beyond the scope of our present task. I have drawn attention briefly to some causes lying just below the surface of our array of threats sufficiently, I hope, to show that they should be included as far as possible in any schedule of parameters used to define the location of a species in its 'space'.

An Example

In 1975 the International Whaling Commission (IWC) established a new procedure whereby all whale stocks would be identified and each one put into one of three categories. This would determine the rules for setting commercial catch limits. In 1982 the IWC extended the procedure to cover aboriginal subsistence whaling and effectively established two new categories.

For most of its existence the IWC's system for setting catch limits practically ensured the depletion of certain species virtually to extinction - the blue and humpback whales in the southern hemisphere, for example. This was the notorious 'blue whale unit' by which a total number of catch units could be filled by various proportions of the five biggest baleen whale species available in the Antarctic. Elsewhere and in the Antarctic distinct Linnean taxa were not distinguished either in statistics or in regulations; these confusions included the sei and Bryde's whales, and the 'normal' blue and 'pygmy' blue whales. The only applicable category was 'protected species' - right whales were always in that category, and blue and humpbacks were eventually added to it, but no objective criteria were ever developed to facilitate the use of this categorization. 'Protected species' were protected only from commercial whaling by members of the IWC, which, until 1979, did not include the majority of whaling countries. The purpose of 'protection' was generally understood to be to remove the danger of extinction; the purpose of setting catch limits for some of the unprotected species, which were not categorized except by default, was supposedly to ensure that catches were sustainable.

Thus the IWC's adoption of the 1975 and 1982 procedure was in principle an important advance on earlier practices, but the difficulties in applying the new procedure have been immense, despite very intensive research to provide the basis for doing so. In fact, the failure of the procedure to bring order into *commercial* whaling was apparent well before the adoption of the 1982 modifications; and many scientists saw that, for lack of scientific basis, the new provisions which related to probabilities of extinction were unworkable. Attempts at the 1983 and 1984 IWC meetings to apply them to Inuit whaling for bowhead whales in Alaska confirmed their present impracticability. Attempts in the late 1970s to change the procedure regarding commercial whaling, to get round some of the difficulties of the early years have been held in abeyance. All the suggestions involved revised categories as well as new consequential rules, but they were even more arbitrary than the original ones.

In its application to aboriginal subsistence whaling, the purpose of the procedure is to allow continued whaling insofar as this is not incompatible with the survival of the 'stock'. In its application to commercial whaling, the object is to maximise sustainable catches. Further, where the current biological state of the 'stock' is not such as to permit maximization, the object of the regulatory regime is to permit the stock to reach that state in a reasonably short time; if the stock is near that state some whaling is permitted; if it is far from it and in an undesirable 'space', commercial whaling is temporarily stopped. It is implicit that if a desirable state for high yield is attained there is no danger of extinction, so that purpose is served automatically.

The first problem in applying the new management procedures is in the identification of discrete whale 'stocks'. The timing of the life-cycles of the most highly migratory species probably ensures that populations in the northern and southern hemispheres are separate. Even so, it is remarkable that there is little evidence of further speciation; for example, sperm whales in both hemispheres are indistinguishable from each other. For the same reason, populations in the North Pacific are separate from those in the North Atlantic.

For the rest, in the southern hemisphere, including the Indian Ocean, as well as for possible separation on east and west of the North Pacific and of the North Atlantic, all distinctions are conjectural. Marking experiments suggest some separation, but they equally demonstrate mixing.

Morphometric studies, blood-typing and the like are all inconclusive. Statistical differences show that mixing is incomplete, but none of the studies permit any estimate of the rates of mixing. Marking experiments are all confounded by shifts in the geographical distributions of recaptures, which come, of course, from the commercial whaling operations.

Thus the IWC has in practice defined 'stocks' in terms of geographical distributions with largely arbitrary boundaries. Recently a small effort has gone into making a range of stock assessments, with a variety of assumptions about stock identity, to establish what practical difference various possible subdivisions might make, but in fact the Commission, and even its Scientific Committee, are very reluctant to consider multiple options when they already have great difficulty in applying the rules they invented in the past decade.

Three categories of a stock subject to commercial exploitation have been established. For each of these a specific rule is given to determine a commercial catch limit in each year. Three categories are also specified for a stock subject to aboriginal subsistence whaling. The boundaries of each set of three are all defined differently. This means that in principle a stock may be classified in one of at least five categories - 'at least' because three null categories ('unclassified') must be identified: classified with respect to commercial but not to aboriginal subsistence whaling; classified with respect to the latter but not to the former; unclassified with respect to both. In fact, most stocks for which any form of whaling is still permitted are in one of the null categories because of so far insuperable difficulties in coming to scientifically based conclusions about their status, or to a consensus among the scientists involved. Apart from that, the scale of the categorization problem is reduced by the fact that IWC considers aboriginal subsistence whaling is conducted on only one stock of each of five species - humpbacks off Greenland, bowheads in the Bering Sea, gray whales in the Eastern North Pacific, and minke and fin whales from East Greenland. Commercial catching is permitted from only one of these five, though only two of them are actually categorized as 'Protected'. Thus there are several unoccupied categories at present.

A further complication are the 'hidden' sub-categories within the various null categories. These involve assumptions - mostly implicit - that a stock is in a certain state, or falls in one or other of two possible categories and not in others, but this cannot be proved. According to the assumption different catch rules are applied.

Throughout the attempted application of these management procedures there has been no agreed definition either of what is a 'whale' or what is 'commercial whaling'. 'Aboriginal subsistence whaling' has been defined, and it is taken that any whaling that is not so defined is 'commercial' by default. Recently attempts have been made to define a third category of 'whaling'. These are politically motivated, since they were a means of continuing some whaling which is certainly not 'aboriginal subsistence' while 'honouring' a 'commercial moratorium'. That such a device is even conceivable is an indication of weakness in the existing definitions. Other factors discussed have been the sizes and types of boats used, whether or not the products are traded internationally, whether the operators of the boats are also the owners and whether they derive a certain fraction of their incomes from whaling and from fishing. This tendency in the IWC to multiply categories to meet real problems will lead to a situation in which there are practically as many categories as there are stocks - or even more.

The IWC has not defined 'whaling', but it is understood to mean the taking of whales by harpoon, deliberately and for consumption. It is directed killing, but does not, apparently, include killing for the purpose of population control or for scientific research, though identical methods would normally be used for either purpose. The 1946 Convention for the Regulation of Whaling, under which the IWC operates, does not permit international regulation of taking for scientific purposes - this is left to the discretion of each State Party, each of whom may issue permits for this purpose - so regulation of *whaling* de facto relates to killing for consumption *only*, since animals killed for other purposes are supposed, so far as possible, to be utilized for commodities.

Neither has the IWC defined what is a 'whale'. There are various interpretations among members, ranging from the view that only those species whose catches are at present being regulated can be called 'whales', through the Danish view that 'whales' are those species listed in an Annex to the Convention (which deals with vernacular and scientific nomenclature), and the view that all cetaceans - or, at least, all marine species - can be called 'whales'. In practice the IWC can only effectively regulate the catching of species for which there is a consensus that they are 'whales'. This situation has led to many problems, not least of which is that while uncertainties remain it is not feasible for states to take other international action (such as forming another organization) to regulate the catching of species not now regulated by IWC.

The IWC categories are shown in the accompanying diagram. The boundaries of categories are defined exclusively in terms of stock 'level', that is with reference to a single variable in the array that would denote the statics of the stock. The quality of that number has also not been defined; it is usually taken to mean the total number of animals or the number over a certain age or size, but there has been discussion of whether in some circumstances it would not be better to refer to biomass. At the same time, it is the number of animals that is of direct interest to the Commission, since it is by common consent that a regime has been sought which will maximise the *number*. There is of course no overriding reason why the same kind of measure should be used to define a category boundary, to set a catch limit or otherwise limit whaling effort and the mortality rate it imposes, and, the ultimate objective, to manage the whaling. The fact that the same kind of measure is used, and somewhat unthinkingly, has led to unnecessarily complex discussion and controversy, even in the Scientific Committee.

The stock 'level' is in principle an absolute quantity. In practice it has been taken in some cases to mean a number relative to the number of whales existing before whaling started - the so-called 'initial stock'. This has happened because it has often proved difficult or impossible to estimate the current number, but it was thought to be easier, using 'indices of abundance' such as catch per unit effort, to trace the decline of the stock through the period of whaling. That this should be expected to manifest a Maximum Sustained Yield 'level' at some fraction of the initial level derives from a particular model of exploited populations of whales. A necessary characteristic of such models is that the stock was in a steady state before exploitation began. In most assessments this is an unproven and untestable assumption. In one case, when it was thought that the population had been increasing before exploitation began (as deduced from the age structure of the exploited population), the procedure was found inapplicable and the stocks had to be placed in a null category. The problem becomes even more complicated if there is reason to believe that other factors are substantially affecting the dynamics of the stock during the exploitation period, since in that case no sustainable catch can be estimated.

Recent studies are beginning to question even whether a whale stock can have a sustainable yield. That is a matter for further scientific consideration. But even if there *is* a sustainable yield it may be too small to be worth taking. This has profound implications for the implementation of the WCS. The concept of an SY and an MSY comes not from empirical observations but from particular kinds of population models; those models are now under critical review.

Even if the general models are accepted as a working basis of assessment and management, there are very difficult practical problems in applying them for categorization. No existing models with wide credibility predict the 'certain minimum level' below which aboriginal catching will not be permitted. This would be true even if some very simple interpretation of 'certain minimum' were to be adopted, such as the locus of a particular rate of change in the probability of extinction within a given period if catching remains at a certain level or if it were to stop. It is almost as difficult to determine what level of population might correspond with MSY, even if it is assumed that one is referring always to stocks in steady states. In the IWC this level has been taken, variously, at 50 per cent, 60 per cent or perhaps in the range 70-80 per cent of the 'initial' level. In practice the Commission uses 60 per cent for baleen whales. This comes, not from any empirical observations on whales, but from theoretical considerations of doubtful validity, tempered by consideration of what is thought to be known about other large mammals.

The uncertainty of the MSY Level would, one might expect, be a matter of contention between those who wish to see whaling of a certain stock continue and those wishing to see it stop. This is because this level, and 20 per cent above it and 10 per cent below it, are critical thresholds in the IWC procedures. There have been periods of debate about this, but in practice it has generally been overshadowed by the difficulty in determining the actual level, or relative level of the stock at any particular time, irrespective of where the boundary is drawn.

A further complication in attempting to apply the procedures to some species such as the sperm whale is that some scientists believe there may be a 'surplus' of males that is not strictly necessary for reproduction. This presumption leads to greatly more complex models, for which there is even less empirical support than there is for the simpler models applied to baleen whales. But even for the latter it has been necessary to define relative stock levels in terms not of total number but of mature or maturing females.

The IWC categorization has illustrated the faults of a single variable definition of 'status'. Thus in certain assessments of sperm whales it was found that although the number of animals might be above the theoretical MSY level for each sex, the *structure* of the population was such that, according to the models, even if whaling were to stop, the population would continue to decline for many years. Thus it was argued that a population in this state should be classified as 'Protected'. In practice such stocks inevitably fall into one of the null categories.

The purpose of categorization tends to lead also to discontinuities in the management rules; in the IWC case to the difference between being able to catch whales or not being permitted to catch them. An attempt was made to overcome this very real practical problem by making the catch limits on a sliding scale when the stock is judged to be above but near to the threshold for complete protection from commercial whaling. Several possibilities were rather superficially examined; the one chosen, essentially arbitrarily, was a linear sliding scale between the MSY level chosen and the level 10 per cent below that. Other suggestions are in the literature, during the period (late 1970s, early 1980s) when the Commission was attempting to revise its procedure with respect to commercial whaling.

From the beginning an effort was also made to take some account of the uncertainty of assessments by providing that catches should not normally be more than 90 per cent of the estimated MSY. In the light of growing awareness of the amount of uncertainty in estimates of MSY, as well as of stock number, this 10 per cent is ludicrously small as a so-called 'safety factor', and in recent years the matter has been made much worse by the setting of catch limits of unclassified stocks in terms of the estimated 'replacement yield' - that is, the yield it is calculated could be taken from a stock (sometimes taking into account its structure as well as its size) while leaving it at the same level the following year. If the structure of the stock is in a far from steady condition - as it is when it is in process of rapid depletion by whaling - the replacement yield can be very different from the sustainable yield expected from a steady state stock of that size; in the situation mentioned it would be substantially higher, and so setting catch limits in accordance with it is more likely to lead to further depletion than setting limits at current sustainable yield estimates. Since the null category is not mentioned in the management procedures, there are no written rules to apply to it; the concept of replacement yield does not appear in the agreed procedures. From this it has followed that even a 10 per cent 'safety factor' has not usually been applied in such cases. The justification given, by whaling states, for rejecting proposals for a safety factor - and, logically, a bigger one than should be applied to sustainable catch limits - is that setting catch limits for unclassified stocks is an interim measure only. The reality is that most unclassified stocks stay unclassified year after year, and the word 'provisional' appears more and more frequently in the Commission's decisions. In fact a stock which at one time is classified is more likely subsequently to become unclassified than the other way round.

In theory the IWC categorization is such that as a stock is further depleted or, alternatively, recovers under reduced whaling or protection, it will be reclassified, and the management rule altered in accordance with that change. In the early days of application of the procedure to commercial operations there was an attempt to do that by, for example, calculating whether a particular southern hemisphere stock of fin whales, which had been protected, might in the near future be exploited again. This was done by running backwards an evidently inappropriate population model used originally to protect that stock. In practice reclassification - and there have been many, sometimes alternating from one year to the next 'like a yoyo', as one exasperated administrator cried - have always been due to revisions in the scientific assessments, not to actual or even to calculated changes in the stocks.

The IWC does not deal with 'threats' to whales other than whaling, though its scientists have from time to time taken note of others. Nor does the Commission deal with changes in habitat or environment which may affect whales, though, again, its Scientific Committee provides a useful forum to discuss some of these. A matter of current concern is the possible effect of fishing for krill in the Antarctic on the southern stocks of baleen whales, particularly the blue and minke whales. Regulatory action, if any, to control that, will be taken by the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), not by IWC.

It should be mentioned that the IWC categorization procedure described here must be seen as one element in a more complex management process. For example, particular types of whaling, such as using pelagic factory ships, are prohibited in certain places and for certain species. In the Indian Ocean Sanctuary all commercial whaling is prohibited (although whales breeding there are subject to exploitation when feeding in the Antarctic); certain methods of killing are forbidden for humane reasons; there are minimum size limits for most species, though not for minke whales, which provide the greater part of current catches; calves and lactating females accompanied by calves cannot be taken legally; and so on. The whole does not now provide a rationally defensible management package. Some of the prohibitions pre-date the IWC itself, and the exact rationale for them is at best buried in the verbatim records of early negotiating conferences, not in scientific papers.

However, the resurgence, in recent years, of these rough and ready, somewhat arbitrary, regulations, is a direct consequence of the overall failure of the New Management

Procedures. These were established - particularly the 1974 decision on commercial whaling - as a 'compromise', essentially as a means of deflecting the growing demand from outside the Commission and, increasingly, from within it, for a moratorium on all commercial whaling. The Procedure had one very important, almost immediate consequence: it led to the protection of a number of greatly depleted stocks. Indirectly it also forced a critical re-examination of the scientific basis for management of whaling. This was very positive. But it also ultimately intensified the demand for a complete pause, as the scientific basis for categorizing and setting catch limits accordingly was found wanting.

All cetaceans are listed on Appendix II of CITES, and practically all those whose catching is regulated by IWC are on Appendix I. CITES Parties decided some years ago that the categorization of cetacean species on CITES Appendices could take account of the need for CITES to support the implementation of IWC decisions. This has led to much discussion also of whether and to what extent the IWC Scientific Committee has a role in advising on the CITES categorization of cetacean species. Much use has been made - loosely, on all sides - of terms such as 'endangered', 'threatened' and the like, showing the need for the present symposium. The outcome is agreement that the decisions by the two inter-governmental organizations - IWC and CITES - call for the applications of quite different criteria, *and rightly so*. But the two sets of criteria do intermesh. They could be derived, as far as population assessment and biology are concerned, from a common, broad database - but much of that database would be outside both IWC's and CITES's terms of reference. The implications of this, and perhaps of similar situations, are worth discussing in the context of this symposium.

Possible categories:

1. AE *Initial management stock*. Total permitted annual catch may not exceed 90 per cent of estimated MSY, or, under specified conditions, no more than 5 per cent of estimated initial stock. Further, exploitation may not begin until a satisfactory estimate of stock size has been obtained, unless exploitation was already in progress before the adoption of the procedure.

2. BE *Sustained management stock* (Sub 1). Total permitted annual catch may not exceed 90 per cent of estimated MSY. If,

3. BF *Sustained management stock* (Sub 2). Total permitted *commercial* catch shall not exceed 90 per cent of MSY less 10 per cent of that for each 1 per cent that the stock is below MSY level, and aboriginal catches shall be such that the stock will move towards MSY level, taking all catches into account.

(Note: There is an alternative criterion for classifying a stock as either BE or BF. This is that it is judged to have remained at the same level ("a stable level") for a considerable period under a regime of constant annual catches, unless there is positive evidence that it should be otherwise classified. This means that the situation can arise - and probably has arisen - when, if there were adequate knowledge, a stock might be classified as CF, or even as CG, and hence protected from commercial or even from all whaling, but where the application of the alternative criterion in the absence of a scientific assessment leads to continued whaling at maximum permissible level.)

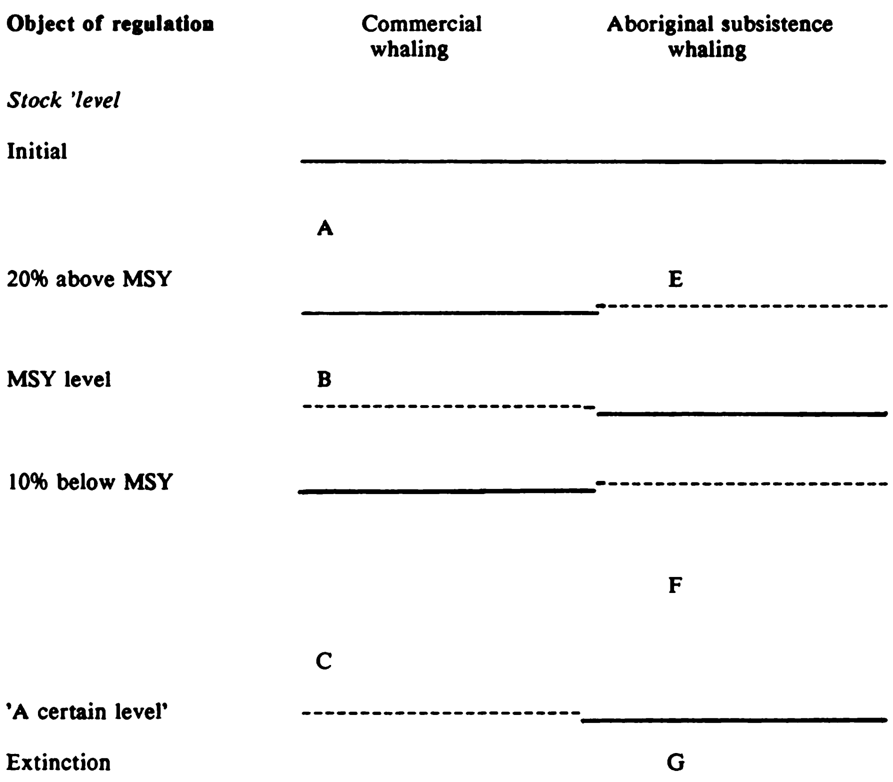
4. CF *Protection stock* (Sub 1). No commercial whaling is permitted, but aboriginal subsistence whaling is allowed with catch limit such that the stock will be allowed to move towards MSY level; thus the catch limit must be less than the current sustainable yield.

5. CG *Protection stock* (Sub 2). No whaling is permitted.

6. D1E
7. D1F
8. D2E
9. D2F
10. D2H1
11. D3H1
12. D3H3, D2H3
13. D2H2

(Note there are no fixed rules for setting catch limits in any of null categories 6 to 13. Boundary between F and G is not yet precisely defined).

Categories of whale stock defined by the IWC Management Procedures



Null categories:
(Uncertain conditions)

D	*H*
D1 (A or B, not C)	H1 (E or F, not G)
D2 (B or C, not A)	H2 (F or G, not E)
D3 (Indeterminate)	H3 (Indeterminate)

ENDANGERMENT WITH THE BEST OF INTENTIONS

Larry D. Harris and Reed F. Noss

1. Introduction

Forests that in 1960 covered approximately one-fourth of the earth's land area now cover one-fifth. By the year 2000, they will be reduced to only one-sixth, and we may, if our efforts succeed, stabilize the fraction at one-seventh by the year 2020 (C.E.Q., 1980: 117). Because forestry represents a low-intensity land use relative to most other forms of human manipulation, deforestation trends pose a serious threat to the preservation of native faunal and floral diversity across the globe.

Perhaps an even more pervasive and serious threat derives from the fragmentation of existing forest into small and/or isolated habitat islands. This is responsible for at least two phenomena: 1, the loss of large, wide-ranging, or 'specialist' species that cannot be 'contained within' patches of inadequate size or high levels of disturbance; and 2, the increasing dominance of remaining fragments by opportunistic, eurytopic (wide-ranging) species characteristic of humanised landscapes.

This pattern of species loss and replacement is not limited to forest species or small forest fragments, but occurs also on a larger scale in parks, preserves and refuges. Even though populations and species succumb one at a time, and thus could be addressed on a species by species basis, the larger-scale pattern is inescapable. The local populations, subspecies, and species that compose native diversity are being lost, often in the face of observed *increases* in species richness at local and regional scales. This is occurring in 'developed' countries as well as the less developed. In this paper we attempt to clarify and re-emphasize certain fundamental notions about diversity and make a plea for conservation programming integrated at the landscape and regional levels. The endangered species approach has been necessary and effective, but we believe progressively greater emphasis should now be shifted towards

1, the comprehensive planning approach,
2. the landscape level of focus, and
3. the integration of conservation and development planning.

This simply elaborates on programmes espoused in the World Conservation Strategy (IUCN, 1980) and the Man and the Biosphere programme (MAB, 1974). Modification and refinement of current approaches will allow more effective integration of preserves into the physical landscape and the social milieu.

2. Native fauna and flora versus biotic diversity

The concept of maximum biological diversity has become a preoccupation of scientists, policy makers and managers (Noss, 1983), as can be seen in recent legislation in the USA (e.g. National Forest Management Act of 1976), in numerous management plans, and as debated in the scientific literature. We find fault with this to the extent that it emphasises total species richness more than conservation of native flora and fauna species in approximately their natural abundances. Habitat fragmentation frequently leads to invasion by and proliferation of species that are either alien or were previously not abundant. The replacement of characteristic species by an equivalent or larger number of widespread, opportunistic forms should not be accepted in the name of conserving biotic diversity. Lovejoy and Oren (1981) observed that 'pursuit of the objective of maximum species diversity or even maximum species richness could lead to serious negative consequences if taken literally....'. In an early discussion of the trade-off between a single large or several small reserves (SLOSS), Diamond (1976) observed that 'the question is not which reserve system contains more species, but which contains more species that would be doomed to extinction in the absence of refuges'. We agree. Strategies and approaches must be developed that conserve entire biotic assemblages in order to prevent impacts from cascading throughout the biological community, thus creating a need for yet more management, and/or endangered species legislation.

These approaches must focus heavily on large, wide-ranging predatory and depredating species for several reasons. First, these species tend to require either very large preserves or functional landscape mosaics in order to maintain viable populations. Secondly, the fact that these species can pose such serious threats to humans and/or livelihoods indicates the key role they normally exert within and upon their own environment. Lastly, if we can establish a system of intensive conservation preserves integrated with extensive conservation easements and management programmes that will work for these flagship species (e.g. large mammal, bird, and reptile carnivores and elephants) we believe it will very nearly suffice for all other species as well. An example will be developed for Florida, USA later in this paper.

3. Maintenance of natural ecosystem processes

Numerous cases of endangerment follow directly from either our ignorance or our insensitivity to the importance of natural ecosystem and landscape processes. These processes include both abiotic (e.g. seasonal burning and flooding) and biotic components (e.g. predation, parasitism, and competition). We believe that, even though the consequences of inadequate choice of area and boundaries will appear as species loss and imbalance of the biotic community within the preserve, the true causes frequently derive from outside the boundaries. Brief accounts to illustrate this point are given below.

3.1 Use or misuse of fire

The suppression and/or misuse of fire has led directly or indirectly to the endangerment or extinction of several North American vertebrates, such as the heath hen *Tympanuchus cupido*, Kirtland's warbler *Dendroica kirtlandii*, dusky seaside sparrow *Ammodramus maritimus nigrescens*, and to a lesser extent the red-cockaded woodpecker *Picoides borealis*. In all these cases over-zealous protection from fire resulted in a greatly modified and unsuitable habitat. In the cases of the heath hen and the dusky seaside sparrow, the build-up of fuel led to overly severe fires that decimated remnant populations. It has been learned that certain species, such as wire grass *Aristida stricta*, occurring in the south-eastern United States, not only require natural or prescribed burning for their survival, but depend on summer fires to ensure production of viable propagules, and have evolved a variety of mechanisms to endure fire or even enhance flammability (Abrahamson 1984). Thus, whereas natural lightning fires burned extensively over a landscape, the creation of passive fire breaks, such as roads, and active suppression have caused recent fires to be more intensive and within given management units.

In East Africa, yet other fire relations prevail. It is well known that the woody vegetation of the savanna parks depends on the interaction of browsing animals and fire. What is not known is the degree to which the ecosystem nitrogen budget depends upon the woody vegetation. In the Mkomazi Game Reserve of northern Tanzania, approximately 80 per cent of the woody plant species are in the combined family Leguminosae. Conversely, approximately 80 per cent of the legume species occur as woody plants (data in Harris, 1972). To the extent that nitrogen fixation is controlled by or limited to the legumes, then the destruction of the arborescent cover may directly affect future productivity levels. Only insignificant amounts of nitrogen are volatilized by normal savanna fires. However, two or three consecutive years of above-average rainfall combined with high elephant depredation (which often happens when elephants are confined to preserves) creates a build-up of dead wood near the ground, causing fires to burn hotter, which in turn kills more trees and may volatilize existing nitrogen bound in the vegetation. If the level of nitrogen fixation is then reduced because of the great reduction of legumes, the entire ecosystem productivity could be altered. Thus it may well be the interaction of animal populations and abiotic processes such as fire that creates long-term cycles in both ecosystem structure and function. Several bird and mammal species, such as the hornbills and the kudu *Strepsiceros imberbis*, are much reduced in the Mkomazi because of such changes.

3.2 Seasonal flooding and water fluctuation

The US south-eastern coastal plain consists of alluvial and marine terraces, generally of low topographic relief, and wide, meandering rivers highly subject to seasonal flooding. The bottom-land forests and swamps occurring in the numerous drainageways are adapted to seasonal flooding, and species such as swamp cypress *Taxodium distichum* are virtually dependent upon fluctuating water levels for survival. Early conservationists and managers thought that water level alone would suffice to maintain these ecosystems. It is now known that even the large biotic preserves such as Okefenokee National Wildlife Refuge and Everglades National Park depend not just on the amount of water available but also on a seasonal hydroperiod that allows drying and germination of species such as swamp cypress, as well as flooding to permit transport of propagules and elimination of potential competitors. Animals, too are often finely tuned to hydroperiod - familiar examples include amphibians that time their breeding to the rainy season and fail to reproduce in dry years, and there are other, less obvious examples. The wood stork *Mycteria americana*, an endangered species in the US, depends on water levels in some intermediate range for successful foraging and reproduction. Water management activities in south Florida have severely altered the sheet flow of water into Everglades National Park from upgradient areas, resulting in drastic reductions in numbers of wood storks and other colonial water birds in the park and elsewhere in the region (Kushlan 1979). In the case of Okefenokee Swamp retainment and diversion levees were constructed so as to stabilize water levels. Despite an explicit policy of ecosystem-level management, no US national park contains an entire support system for colonial water birds (Kushlan 1983). Processes operating outside each park ultimately determine the species composition and abundances within.

Thus conservation of endangered species and perpetuation of native floral and faunal diversity, even in these large preserves, depends not only on the habitat *content* within the boundaries, but also on the landscape *context* in which each preserve rests. These preserves are not closed, self-supporting systems, but rather parts interacting within still larger systems.

3.3 Biotic interactions

As indicated earlier, certain types of species are lost from insularizing preserves and forest fragments. Losses occur when the area is simply too small to support viable populations, or when the disturbances that accompany smaller size and envelopment in a humanized landscape are unfavourable to specialists. Such disturbances include human habitat alterations and harassment, as well as edge effects. These in turn affect active biotic processes such as predation, brood parasitism, and nest-site competition.

Fragmentation of the deciduous forest in the eastern United States has received much recent attention (e.g. Burgess and Sharpe 1981), and birds have proved good indicators by which to measure faunal change. Although the number of local bird species, as with other taxa, often rises with forest insularization and disturbance, deluding some managers into thinking fragmentation is beneficial to wildlife (review in Noss 1983), the changes are away from native forest species and towards widespread 'weeds'.

Recent studies suggest that biotic interactions may figure prominently in the avifaunal deterioration of the eastern deciduous forest. Long-distance migrants, which typically compose 80-90 per cent of the avifauna in large forests, are outcompeted in forest fragments by permanent residents and short-distance migrants (Whitcomb et al, 1981); apparently their life-history characteristics predispose them to nest depredations from small mammals, jays, crows, grackles, and other predators, to nest-cavity competition from European starlings *Sturnus vulgaris*, brood parasitism from brown-headed cowbirds *Molothrus ater*, and other problems associated with small forest patches with abundant edge (Gates and Gysel 1978, Whitcomb et al. 1981, Ambuel and Temple 1983). The cowbird, which was probably not found much east of the Mississippi River prior to forest fragmentation, has a particularly severe impact on eastern forest birds unadapted to its parasitism (Brittingham and Temple 1983).

The combined impacts of insularization and internal disturbance (habitat manipulation, swaths, and heavy visitation) on avian composition was noted by Noss (1981) in an Ohio forest reserve, where long-distance migrants constituted only 39 per cent of the species and 22 per cent of the individuals. Species richness was extraordinarily high (61 breeding species), but composition was weedy: a known nest predator, the common grackle *Quiscalus quiscula* ranked first in relative abundance, with European starlings ranked seventh, and cowbirds tenth. As with many other fragments of eastern deciduous forest, the character of this ecosystem has been severely compromised. It is not known how far this results directly from insularization or indirectly from habitat alterations and population impacts in the neotropical overwintering regions (Briggs and Criswell 1979).

4. Landscape ecology and the island archipelago approach

The dominant message so far is that we should focus, not on biotic diversity *per se*, but on the preservation of characteristic floral and faunal assemblages, and that to think in terms of individual preserves out of the regional or landscape context will seldom lead to success. Even when we succeed in establishing several large preserves in the region, such as occur in East Africa, their integration into the regional landscape ecology and social milieu poses a variety of problems.

4.1 Multiple-use modules

The concept of multiple-use modules (MUMs, Harris 1984: 161) constitutes a refinement of original Man and the Biosphere reserve proposals (e.g. MAB 1974) and can be applied at all levels of biological hierarchy. In a MUM, a central, inviolate core area (or areas) is surrounded by more intensively used buffer land. For example, a stand of mature longleaf pine *Pinus palustris* is essential nesting habitat for the endangered red-cockaded woodpecker of the south-eastern US and older pines are also preferred foraging habitat. Thus nesting is not compatible with short-rotation plantation management, but a considerable amount of foraging habitat can be under intensive management. Therefore, MUMs provide a mechanism for integrating a moderate-sized island of old-growth longleaf pine into a landscape of short-rotation pine plantations. The same approach applies to spotted owl *Strix occidentalis* management in the north-western US and to numerous other species.

At a slightly higher level, the concept of multiple-use modules can be applied to old-growth forest conservation. In this case, a tract of old-growth forest, ranging in size from tens to hundreds of hectares, can be surrounded by long-rotation timber management stands. Numerous advantages derive from the use of such planning modules, but again the approach is aimed at integrating conservation planning with more intensive development planning (Harris 1984).

The designated wilderness system of the United States occurs predominantly on National Forest land. By definition these areas should be roadless and, to a large degree, they should be isolated from human activity. Forestry operations are not permitted within wilderness areas, but since forestry is a relatively low-intensity form of land use, we could probably not choose a better setting for wilderness than managed forest.

The concept of multiple-use modules has great utility even at the level of wildlife refuges, parks and preserves. While certain core areas must be kept off-limits to hunting and other consumptive use, extreme population fluctuations of certain species in what is still a modified (e.g. insularized or predator-depleted) setting may necessitate cropping. Rather than allowing this to occur within the primary preserve area, it seems advisable to restrict cropping to a buffer zone surrounding the core. In situations where protein deficiencies are rampant among the human population, such cropping schemes represent the most promising way of establishing and maintaining citizen support for conservation programmes.

The general idea of the core preserve being surrounded by two or more 'soft boundary' buffer areas is not new. On the other hand, we believe the hierarchical extension of this same concept to scales ranging from an individual clan of woodpeckers, to old-growth management strategies, and to parks and preserves, does constitute a significant refinement of present thinking.

4.2 Travel corridors and connectivity

Even the best designed preserves, buffer zones and all, will rarely be extensive enough to maintain minimum viable populations of many large, wide-ranging species. Nor will they be extensive enough to maintain characteristic species composition and diversity by incorporating a natural disturbance regime and recolonization sources (Picket and Thompson 1978). Rather, in most regions of the world we must rely on integrated networks of preserves and other undevastated fragments of land to maintain the whole system.

Applied biologists have talked for years about the need for linking devices, such as forest corridors or stepping stones of small forest tracts, to encourage dispersal of species between habitat islands (Willis 1974, Diamond 1975). Wide-ranging species like Florida panthers or grizzly bears need to move, and a system of isolated preserves will fail miserably. It will also fail a society somewhat unnerved by panthers or bears in their backyards. The obvious way to facilitate movement and gene flow, while avoiding unnecessary encounters (dangerous to both animals and humans), is to connect preserves and other blocks of undeveloped land with wide corridors of suitable habitat (Forman and Godron 1981, Noss 1983, Harris 1984). Unfortunately, we have seen few instances where the importance of connections has been recognized in conservation or other land-use plans.

4.3 Fitting the island archipelago to the landscape

The issues of appropriate size, shape, and connectivity of habitat islands have been debated from the conceptual and academic viewpoints, but we find that critically important aspects of landscape topography, ecosystem function, and propagule dispersal have not received adequate attention anywhere. Resources are not distributed randomly throughout the landscape, nor do animals move about and disperse randomly. Ecosystem productivity is almost invariably higher on rich alluvial soils in bottomlands, and water is more predictable there; this suggests that conservation areas on such sites could be much smaller and still support the same abundance and diversity of wildlife as would occur on larger but poorer areas. Of course, a comprehensive approach to conserving native diversity must include representatives of all ecosystem types.

Even though our knowledge of dispersal patterns of plants and animals is limited, it seems clear that landscape features play an important role in facilitating the dispersal process. Natural features such as riparian forests, topographic ridge systems, ecotones between major vegetation types, and even human cultural artefacts (e.g. road verges) or historical animal trail systems and migration routes, should be designed into the archipelago system. The important point is to design with nature to the greatest extent possible, and judge the appropriateness of system components from the viewpoint of the organisms involved, not from the anthropocentric bias of aesthetics, politics, or provincialism.
3Close inspection will reveal a pattern in the resource distribution in any region where natural features still persist. The pattern may appear as dendritic (tree-like) drainage systems, repetitious hill and valley, dune, or soil sequences at reasonably constant intervals, or perhaps polygonal or circular associations of landform, soil, and vegetation. Whatever the pattern, attempts should be made to interpret the scale of size, sequence, and distribution. This quantitative and qualitative information should prove invaluable

in guiding decisions regarding size, shape, distribution, and connectivity of the preserve archipelago system. If we are concerned with native diversity, we cannot afford to ignore large-scale patterns in land-use design.

5. An Example from the South-Eastern United States

We have suggested that certain kinds of species, notably large carnivores and various ecological specialists, tend to disappear in fragmented landscapes. Their loss even within protected areas, and their replacement by widespread, eurytopic species that do not need preserves for survival, sets in motion a trend of global homogenization, often in the face of observed increases in species richness at local or even regional levels. We have also suggested that these fragmentation side-effects can only be ameliorated by tailoring a preserve system to the landscape, and integrating the processes of conservation and development planning.

Florida is fortunate to have over 400 managed areas encompassing over 5 million acres of land, but these areas are not as interconnected as they should be, and biological impoverishment and homogenization are proceeding at a rapid pace with the fastest-growing human population in the US. Despite drastic alterations to native ecosystems, we still have a chance to restore integrity. Red wolves have been eliminated and panthers are down to a pitiful 20 or 30 individuals, but alligators have recovered from past lows and with proper planning remnant black bear populations can be maintained. If we are to save these large carnivores, critical indicators of ecosystem integrity, we must work now to integrate conservation and development and tie together a system of protected areas into a functional network.

Two networks of multiple-use modules connected by riparian corridors are proposed for the North Florida-South Georgia region. This is a region with several large and reasonably well-protected preserves, but they are disjunct and unlikely to maintain ecological integrity or genetic flexibility in their constituent species or serve as auspicious sites for reintroducing panthers and other lost forms. Unlikely, that is, unless they are interconnected.

The first MUM Network would link the Okefenokee Swamp, most of which is National Wildlife Refuge, to the Osceola National Forest (Fig. 1). The Suwannee River, now being considered for federal status as a wild or scenic river, but with some recent setbacks, would then form the nexus, a broad riparian corridor connecting these preserves to other managed areas on the Gulf of Mexico coast, including the Lower Suwannee River, Cedar Keys, Chassahowitzka, several state parks, reserves, and proposed acquisitions, wildlife areas, and other lands and water under some form of protection (e.g. designated critical habitat for the endangered West Indian manatee). All these managed areas would be inviolate core areas, except for utilized portions of Osceloa National Forest and recreation-oriented state lands, and would be surrounded and linked by cortical buffers where more human uses were permitted.

MUM Network 2, in the 'Big Bend' region of the Florida Panhandle, would link the Apalachicola National Forest, St Marks, St Vincent Island, Apalachicola State Aquatic Preserve, several state parks, and a large preserve managed by the Nature Conservancy. All these would be core areas except for utilized portions of Apalachicola National Forest and recreational state lands. The Apalachicola River corridor, an area of high endemism with several endangered species, would be protected as a broad strip from its mouth to Lake Seminole on the Florida-Georgia line. Buffer zones would surround the whole complex and furthermore, link it to MUM Network 1. Once the areas are functionally interconnected, biologists can get to work reintroducing large carnivores and other missing ecosystem components to each network. If we set our minds to it and act accordingly, ecosystem integrity *can* be restored.

We believe that these MUM Networks constitute a reasonable, practical conservation plan, given the political will and interagency cooperation to make them a reality. That is where we must now direct our efforts not only in Florida but in every region across the globe. The native diversity of regional landscapes depends on these efforts.

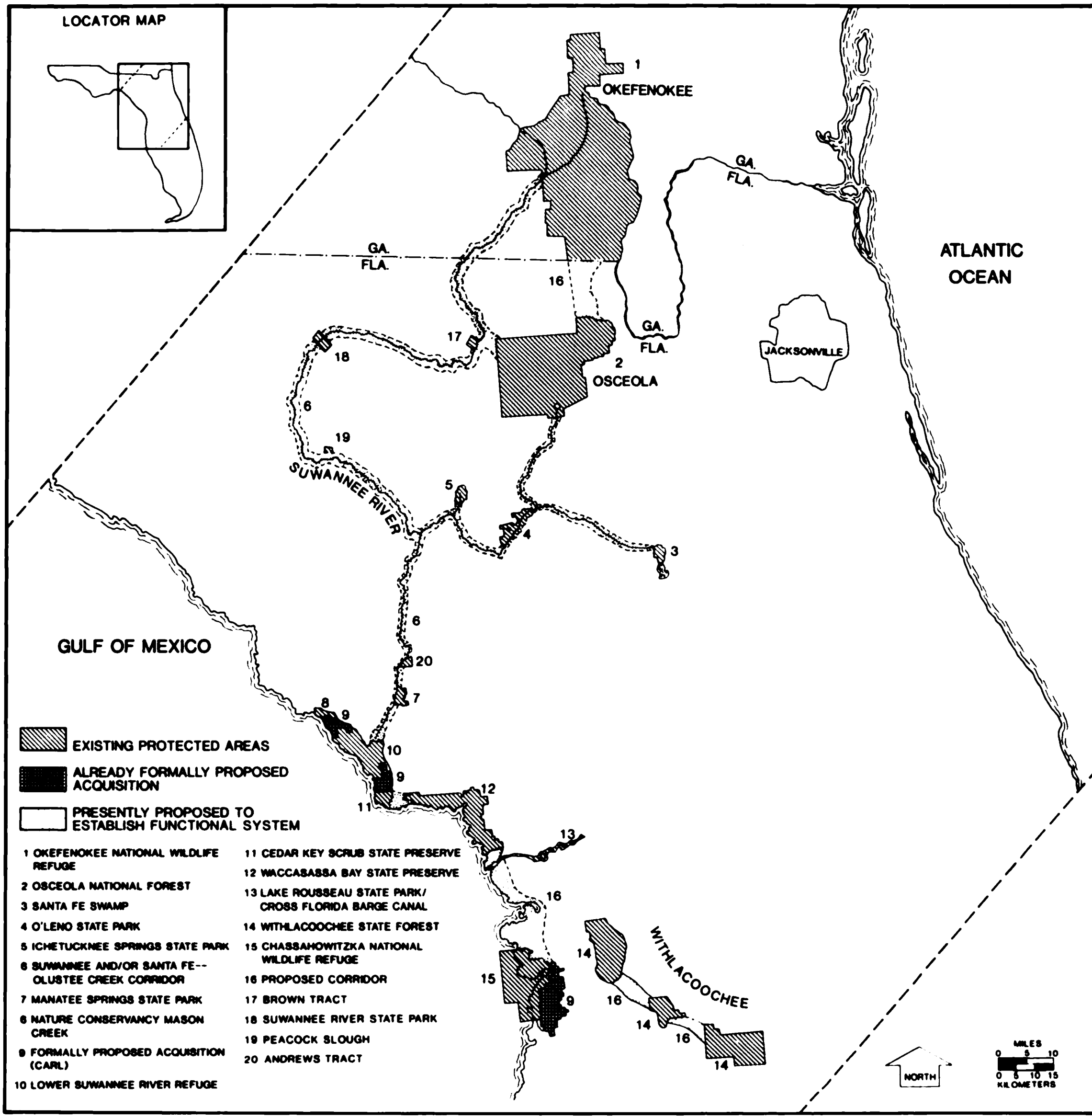


Figure 1. Habitat islands of north-central Florida and south-east Georgia showing the potential for interconnection with multiple use corridors.

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LEGAL EXPERIENCE AND IMPLICATIONS

Michael J. Bean

This paper examines some of the practical consequences of categorizing species as endangered, threatened, or some similar designation. Specifically, it focuses on the legal implications and actual experience of such designations under the Convention on International Trade in Endangered Species (CITES) and under the domestic laws of various nations. Usually such designations trigger only limited prohibitions on hunting and trade, but sometimes they lead to a wide range of far-reaching consequences, including some that may not be immediately apparent but raise important conservation policy issues.

History

Historically, the concepts of 'endangered' and 'threatened' as formal conservation classifications are relatively recent. Certainly, governmental efforts to protect species from overexploitation or other threats pre-date their general use. On the international level, for example, Canada and the United States agreed in 1916 to prohibit or closely control the hunting of migratory birds. Although the then recent extinctions of the passenger pigeon *Ectopistes migratorius* and the Carolina parakeet *Conuropsis carolinensis* gave impetus to this treaty, both its purpose and its effect were broader than just preventing further extinctions. The principal concerns of those early drafters were the agricultural benefits provided by insectivorous birds, the aesthetic enjoyment of songbirds in general, and the recreational benefits of gamebirds. Similar concerns underlay the 1902 European Convention for the Protection of Birds Useful to Agriculture.

At the national level, too, laws to protect species from overexploitation or other threats were widespread and well developed long before the modern preoccupation with endangerment became deeply rooted. Often their object was to assure a sustainable yield of food, hides, or other products. So the modern laws and treaties that focus on preventing extinction were often superimposed on an existing, well developed system of conservation regulation with established institutions to administer it and diverse interest groups subject to it. In some respects, the institutional and interest group adjustments necessitated by these more recent laws have been among the most important factors in determining the success of the new initiatives.

THE CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES (CITES)

Appendix I

This point can be illustrated by reference to the most familiar example, CITES. This is a treaty addressed to a single conservation problem. All international commercial trade, or more precisely, the use of internationally traded specimens for primarily commercial purposes, is prohibited for species placed on the treaty's Appendix I, i.e. those determined by a two-thirds majority of CITES parties to be 'threatened with extinction (and) which are or may be affected by trade'.

Several observations are pertinent here. The first is that the treaty's formulation of words describing those species appropriate for Appendix I listing is necessarily general and susceptible to varying interpretations. Even with the aid of the more detailed criteria developed by the parties at their meeting in Berne, Switzerland in 1976, the ultimate judgment whether a species properly belongs to Appendix I remains one about which reasonable people can and do differ. As a result, the procedural mechanisms of decision by two-thirds majority vote assumes considerable importance. Those in the minority on a vote to add a species to Appendix I face a difficult dilemma: either bow to the will of the majority and sacrifice their trade benefits or repudiate the majority by filing a formal reservation. This is a treaty-guaranteed right, but in practice there are a myriad of pressures against it, not the least being that a reserving party may find itself without any trading partners unless others also reserve.

The superimposition of these new trade controls on existing regulatory and management programmes, interest groups, and trading networks may cause, and has caused, significant strain. Take, for example, a country that has what it believes is an effective management programme for a species that is later placed on Appendix I. Once international trade in that species is substantially curtailed, the ability of its management programme to generate foreign exchange, which may be an important factor in justifying it, disappears. Alternatively, consider the example of a country that invests heavily in a management programme to restore its population of an admittedly endangered species to a condition in which controlled trade no longer presents a threat. Unless and until a two-thirds majority of CITES parties agrees to remove that population or species from Appendix I, such trade may not be permitted, and one of the potential benefits of the successful restoration programme cannot be realized. Disatisfaction with the 'all or nothing' character of Appendix I lies at the heart of many recent and current CITES controversies, among them the recurring efforts to relax the 'downlisting' criteria for species listed prior to the Berne meeting, the effort in Botswana to fashion some mechanism for permitting limited trade in leopard products despite the leopard's Appendix I listing, the attempt in New Delhi to fashion special rules permitting trade in 'ranched' specimens of Appendix I species, and the controversies over proposals to remove the Nile crocodile and other commercially valuable species from Appendix I to be expected at Buenos Aires in 1985.

Appendix II

The problems of accommodation and adjustment are by no means limited to Appendix I species. For Appendix II species, CITES offers a similarly nebulous and general definition: those 'not necessarily now threatened with extinction (but which) may become so unless trade...... is subject to strict regulation in order to avoid utilization incompatible with their survival.' Compounding the potential for confusion and conflict from the definition, however, is the fact that the CITES parties harbour two fundamentally different notions of the functions of Appendix II. For some, including the United States, it is to assure fairly rigorous control over trade in species known to be in a 'worrisome' conservation status but not yet in imminent danger of extinction. For others, including many European nations, Appendix II serves as a vehicle for 'monitoring' rather than 'strict regulation'. As such, Appendix II is a proper place not only for species whose conservation status is known to be worrisome, but also others about whose actual conservation status very little need be known. Put differently: the European view is that the monitoring made possible by Appendix II can serve as a means to find out more about the status of species, while the official American view is that the purpose of Appendix II is to ensure that international commercial trade is controlled strictly enough to prevent it from further jeopardizing species already known to be in some jeopardy.

These different conceptions might not matter very much, but for the problem of meshing the new CITES requirements with existing regulatory and management programmes. One of the key practical consequences of designating a species as endangered or in some similar category is that the responsibility for its conservation may shift, in whole or in part, from one level of government to another. This is true in federal systems like those of the United States and Argentina. In the domestic legislation of both countries, the designation of a species as endangered brings with it new national government conservation responsibilities for species previously the primary responsibility of the state or provincial governments. Not all federal systems operate in this way. In Canada, for example, national government authority is so limited by the constitution that conservation and management authority for most species rests almost exclusively with the provincial governments. In the United States the listing of all wild cats on Appendix II obliged the federal government to assume a prominent role in the management of a species hitherto managed exclusively (and in their view successfully) by the states. The jurisdictional friction thus generated substantially undercut support for CITES from an important section of the US wildlife conservation establishment.

NATIONAL AND LOCAL LAWS

Trade and Taking

Under the domestic laws of many, if not most, countries, the designation of a species as endangered carries with it prohibitions against the hunting or trade or both, but little else. Such countries include Brazil, Costa Rica, Panama, and Peru. Usually there are limited exceptions for such favoured purposes as scientific research (Costa Rica, Peru), captive breeding (Costa Rica, Peru), and cultural purposes (Peru). Curiously, these prohibitions are sometimes in addition to other enactments prohibiting all wildlife trade or hunting, as in Costa Rica.

Even if fully enforceable and effective, laws of this character would be of little avail to most species threatened with extinction. What is needed is more broadly stated authority to carry out affirmative conservation programmes to aid their recovery, entailing not only the regulation of hunting and trade, but also the management of other activities affecting the species or its habitat. Surprisingly, the laws of very few countries contain a specific grant of authority to carry out such a programme; instead they are framed in the negative, prohibiting hunting and trade but ignoring altogether the more subtle and insidious factors contributing to the decline of many species. A few jurisdictions introduce a novel variation when the subject is endangered plants. In California, before a landowner may develop land on which an endangered or rare plant occurs, he must notify state authorities, who may then enter the land for purposes of 'salvaging' the protected species. Pennsylvania employs a similar system of licensed private 'salvagers' of rare plants otherwise faced with destruction through land development.

Habitat Protection

Let us examine more closely some of the few laws that seek a broader reach. In Canada, the provincial endangered species laws of Ontario and New Brunswick prohibit the wilful destruction or interference with the habitat of any endangered plant or animal (Ontario) or the destruction of the habitat of any endangered plant (New Brunswich). The Ontario legislation is likely to be of limited practical value because its prohibition applies only to 'wilful' acts, and, although this has yet to be officially interpreted, it is likely to be limited to acts of habitat destruction done for the purpose of harming the endangered species. Both statutes share the definition problem of what the term 'habitat' really includes. If it encompasses the entire range of an endangered species, it could be extraordinarily broad; but if it is intended to refer to something narrower, its scope remains uncertain.

The US Endangered Species Act attempts to define protected habitat of an endangered species and delineate the scope of its protection. This introduces the concept of 'critical habitat,' which may be either coextensive with the current range of the species, more limited, or in some cases even broader, and it means those areas which must be protected or specially managed to prevent the extinction of the species and bring about its recovery. It is required to be formally designated for each new species added to the threatened or endangered list, except for those likely to be harmed if their precise location is published.

Not all persons are prohibited from harming critical habitat. Indeed, the concept of critical habitat was developed as a means of restraining government action rather than private action. Basically, each federal government agency, whether its mission be road building, dam building, or regulation of private development, is prohibited from any action that destroys or adversely modifies the critical habitat of any listed species or otherwise jeopardizes the continued existence of any such species. Similar restraints on state government agencies are imposed by the laws of California, Maryland and Nebraska, among others.

As a result of the Act's very broadly defined prohibition against 'taking' endangered species, purely private actions, while not formally subject to the Act's critical habitat prohibitions, may be prohibited if they affect the habitats of such species. 'Taking' is not limited to direct forms such as hunting or trapping, but also includes 'incidental' taking as a result of habitat destruction. Thus, many private development activities occurring on privately owned land come potentially within the sweep of the Act's broad taking prohibition.

Categories of Species

Thus far, apart from the initial discussion of CITES, this paper has not distinguished among the various categories of protected species based on the degree of threat they face. Drawing such distinctions appears to have absorbed a considerable amount of the effort of the compilers of red data-type books. Proposals to split existing categories into even more numerous sub-categories, separated on the basis of increasingly subtle nuances, are recurrent. Whatever the scientific merit of such efforts, experience to date suggests that national laws and administrative programmes to implement them are not likely to respond.

The two-tiered approach of CITES, dividing protected species into those now threatened with extinction and those likely to become so in the future, is substantially replicated in the US Endangered Species Act, in which those two categories are designated, respectively, as 'endangered' and 'threatened'. For endangered species, the Act's prohibitions are fixed and inflexible. For threatened species, it was intended to provide the flexibility to tailor regulatory requirements to fit particular conservation needs. The 'threatened' classification was designed to enable the government to take prophylactic measures to prevent a species declining to the point at which the rigid restrictions applicable to endangered species are necessary. Interestingly, however, the threatened classification has been relatively little used and, when it was, it has most often been accompanied by restrictions virtually identical to those that apply automatically to endangered species.

In countries whose endangered species laws extend protection only against hunting and trade, more detailed classification systems offer little additional flexibility. A broadly worded mandate to impose such restrictions on hunting and trade and to take the actions necessary to prevent the extinction and ensure the recovery of endangered species is likely to be more valuable than a sophisticated effort to design a hierarchy of species classification and attendant regulatory restrictions. Thus in Pennsylvania, the Wild Resource Conservation Act directs the state's Department of Environmental Resources to classify the state's wild plants into one of nine categories. Oddly, however, for six of these categories the statute gives no guidance as to the legal consequences of the classification, and for two more they appear to be identical.

Some Other Practical Consequences

Endangered species designation can, of course, have significant consequences quite apart from the operation of the laws. For example, legislation authorizing the establishment of ecological reserves often identifies endangered species protection as one of the purposes for which they may be established, as in New Brunswick and numerous states of the USA.

Another important way in which such designations function is through environmental impact assessment requirements. In the USA, the National Environmental Policy Act requires the preparation of an environmental impact statement for all major federal actions that significantly affect the quality of the environment. In practice, any action likely to affect adversely any endangered species, by virtue of that fact alone, requires a full environmental impact statement.

Moreover, endangered species designations often trigger conservation initiatives from non-governmental interests. The US Nature Conservancy, a non-governmental organization that acquires and preserves large areas of natural habitat, uses the endangered and threatened species lists under the US Endangered Species Act to help order its own acquisition priorities.

Not all the practical consequences of endangered species designations are beneficial to their conservation, however. Where governments lack the resources to protect adequately the species they designate as endangered, designation can focus increased interest on the species by unscrupulous collectors and traders. There are numerous examples of this in the United States, particularly with species that have been identified for likely future listing. Similarly, although most endangered species laws allow taking and trade in protected species for scientific research and conservation purposes, the paperwork and delay in processing such requests has dismayed many who otherwise strongly support the goals of such laws. A good example recently was the delay experienced by the Guam government in getting approval to enter an Air Force base to capture endangered birds for use in a captive propagation programme, which threatened the success of this last ditch propagation effort.

A more intangible danger is that inherent in the 'loading up' of endangered species lists with species whose conservation status is in fact less precarious. As we have seen the generality and ambiguity of the definitions that govern such classifications are such that plausible cases can be made for adding many species. If taken seriously, the effect will be to spend limited resources on species that do not need urgent attention. On the other hand, if such lists are not taken seriously, then that fact in itself is likely to undermine the popular and scientific support for what all of us believe to be one of the most urgent conservation imperatives of the day.

RED DATA BOOKS: FUTURE PERSPECTIVES AND NEEDS

V. Sokolov

This summary of Dr Sokolov's paper is based on notes supplied by him.

The IUCN Red Data Books have both ensured a fundamentally new scientific approach to the conservation of rare species, and drawn public attention to the problem, so that rare species have begun to be regarded as a public asset. Inevitably they have led to the compilation of national RDBs. These were originally expected to include only species in the IUCN RDBs, but the national compilers soon decided to include species that were endangered or threatened only in their own countries. Indeed, the IUCN RDBs should logically be based on the national ones, and species should only be transferred from one RDB to another after critical analysis.

In 1978 the Soviet Union published the *Red Data Book of the USSR* (Bannikov 1978), and the second edition is under way. This lists 62 mammal species and subspecies (92 in the second edition), of which only 24 appear in the IUCN RDB. Many of these are rightly omitted, such as the goitred gazelle *Gazella subgutturosa*, rare in the USSR but numerous in Mongolia. But others should be included, such as some of the subspecies of mountain sheep endemic to the USSR, the Asian beaver *Castor fiber pohlei*, the jerboas *Salphingotus crassicauda* and *Cradiocranus paradoxus* and the dormouse *Selevinia betpakdalaensis*.

It is vital to stimulate the composition of national RDBs, so that eventually every country will have one and in larger countries also one for each of their major administrative subdivisions. In the USSR we already have RDBs for several of our constituent republics, including the RSFSR, Ukraine, Byelorussia, Kazakhstan, Moldavia and Georgia.

Listing a species in a Red Data Book undoubtedly helps in its preservation, since the presence of rare species is an important factor in the designation of protected areas. The publishing of national and regional RDBs also focuses attention sharply on locally rare species, and promotes research on them where they are commoner as well as on how to protect them under the harsh conditions at the periphery of their range. This is an important step towards retaining the genetic diversity of many species.

An understanding of their biology is essential to the conservation of rare and endangered species. So both the theoretical basis and the practical details of such basic biological sciences as systematics, biogeography, ecology, ethology and genetics must be developed if we are adequately to protect rare species. In particular, there is a special need to develop and apply 'soft' study techniques, to avoid killing rare animals.

No species can survive unless an adequate sample of the diversity of its subspecies and discrete populations is preserved. Yet our present knowledge of the biology of the great majority of species is superficial and inadequate. In particular, how can we know enough about subspecies and populations when the very criterion of subspecies is uncertain?

The current widespread destruction of natural and semi-natural habitats affects large mammals much more than small ones, because they need larger territories. This is why most of the species in the IUCN Mammal RDB are those which weigh more than 100 kg, and many other larger species may have to be included in future. Thus the RDBs can be used to forecast which species are likely to become endangered, as well as being a register of existing status.

On the other hand, many mammal species with a limited range are omitted from the current Mammal RDB. An inventory of known centres of endemism and diversity, and research to discover new ones, would be a great help in compiling future RDBs. Such an inventory for the ancestors of cultivated plants, compiled by N.I. Vavilov in the 1920s, resulted in large collections of invaluable genetic material from such centres of endemism; these have been preserved in the USSR as invaluable material for plant breeders.

One important measure to promote species conservation in the USSR is the establishment of a network of bodies to act as curators of endangered species. Every species listed in the USSR RDB is to be assigned either to a research institute of the USSR Academy of Sciences, or to a university, or directly to one of the Union republics, to monitor its status and study its biology. Thus, the Far East Scientific Centre of the USSR Academy of Sciences has been nominated curator of the Far Eastern large cats - tiger *Panthera tigris altaica*, leopard *Panthera pardus orientalis* and Amur wild cat *Felis bengalensis euptilura* and the Turkmen Academy of Sciences is in charge of the Asiatic wild ass *Equus hemionus onager*.

Recently the USSR Council of Ministers issued a special decree to draw up an inventory of the Animal Kingdom of the USSR, which, it is hoped, will substantially improve the database for nature conservation in the USSR. Coupled with this one must draw attention to the expanding network of reserves, now numbering 137.

Many mammals have been overexploited in the past, so that species on which some primitive tribes depended for their welfare have become extinct, or nearly so. The Pacific walrus *Odobenus rosmarus divergens* is a good example. The Chukchi, who inhabited the south-eastern coast of the Chukotka peninsula in north-eastern Arctic Siberia, used to manage the walrus colonies on Arakamchen Island carefully, only hunting them at special sites. But at the end of the 19th century, when they began selling walrus tusks, all the colonies were destroyed, and it is only in recent years that their numbers have substantially recovered. Some scientists believe that the mammoth *Mammuthus primigenius* was exterminated by man, although my own opinion is that man was not the decisive factor.

It is also well known that war is an extremely harmful influence on wildlife, especially large mammals, as in the notorious example of Vietnam, where the numbers of large and medium-sized mammals were very severely reduced.

To conclude, the USSR's current programme of work on the RDBs will comprise:

(1) the expansion of the list of species and subspecies included, together with isolated populations;
(2) the refinement and analysis of quantitative and qualitative criteria;
(3) more rapid exchan e and processing of data through databases;
(4) elaborating global and regional predictions of the status of species;
(5) elaborating a multi-sided approach to the selection of protected areas and vulnerable regions; and
(6) elaborating the technology of nature protection and recycling resources so as to stop the impoverishment of gene pools.

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SYNTHESIS AND RECOMMENDATIONS

W.A. Fuller

In his summary of the papers and the discussion that followed, Dr Fuller distinguished four themes: history of the Red Data Book idea, categories of endangerment, legal implications, and management of endangered species. After dealing briefly with the first of these, he summarised and commented on the remaining three.

Categories of Endangerment

Munton provided an exhaustive list of categories that have been used as markers on the Road to Extinction (Chapter 9) and parameters that may be used to arrive at a category. Holt gave us three reasons for categorizing, namely:

1. to convey a perception to the lay public,
2. for use in drafting laws (but see below), and
3. for use by professionals in programme development and setting priorities.

Munton suggested retention of a serial system of categorization such as Vulnerable-Endangered-Extinct, whereas Holt recommended a multifactor approach that would locate a species, surrounded by a cloud of uncertainty, in multidemensional space.

King listed what he called 'marker phenomena' that can serve to identify 'the status of wild species and the threats leading to their extinctions'. His markers are an amalgam of changes in population dynamics and other biological parameters, reductions or alterations of habitat, and the kinds of threats that a species faces.

Munton, Holt and Tillman in discussion all caution against using numbers to define categories, because publishing a number may give a false impression of precision. It is true that a census of a wild species may be difficult to obtain and that confidence limits for a census may be virtually impossible to calculate. It is also true that abundant species, such as the passenger pigeon of North America, have been driven down the road to extinction in a short time. On the other hand, as Munton points out, rarity *per se* is not necessarily an indication of impending extinction. In what follows I attempt to lay out a step-wise method of arriving at a categorization of a taxon without recourse to numerical abundance, except in a very general way.

The first step is to take into consideration a few generalizations about the distribution and social behaviour of the taxon. I illustrate this step by means of a short key for use with terrestrial animals.

1.	a.	Distribution continuous or nearly so (continental)	2
	b.	Distribution sharply discontinuous (islands, both geographicaland ecological, relicts)	
2.	a.	Found on more than one continent (cosmopolitan, holarctic,pan-tropical, etc.)	
	b.	Confined to one continent	3
3.	a.	'Social' species - occurring in large herds or flocks	4
	b.	'Solitary' species - occurring singly or in small family groups	5
4.	a.	Members of a climax community or requiring special habitats	I
	b.	Occurring in successional stages or ecotones	II

5. a. Members of a climax community or requiring special habitats — III
   b. Occurring in successional stages or ecotones — IV

6. a. Good colonizers — 7
   b. Poor colonizers — ?

7. a. etc.

Further refinement of such a key could make special allowance for migratory species that depend upon the sanctity of two separate ranges, cyclic species that undergo wide oscillations in abundance, and perhaps other special circumstances. It may also be useful to distinguish between taxa that were initially abundant (say a million or more?) and those that have always been rare (or secretive?). Perhaps wetland species require a key of their own. Certainly, a different set of initial conditions must be defined for marine species and communities.

Inclusion of community type and successional stage may require a further word of explanation, but some examples may make their significance clear. The bison in North America, a social, climax species, was driven to the edge of extinction in a couple of decades. On the other hand, the solitary, climax moose *Alces alces* has, up to now at least, persisted rather well. Another large mammal, the wapiti *Cervus canadensis*, which, although social, is not confined to a single climax type, has also done rather well. The coyote *Canis latrans* is an outstanding example of a non-social, non-climax species, which has actually extended its range in the face of persecution by man.

Some of the reasons for the above differences are transparent. Social creatures are ready victims of mass slaughter, whereas the solitary types must be pursued one (or a few) at a time. Species with rigid habitat requirements are specially at risk as a result of human modification of landscapes and ecosystems - for example, whooping cranes and the conversion of native grassland to wheatfields.

A scheme such as this provides a preliminary classification without any explicit reference to threats. Not much information is required to make such a preliminary assessment. For continuously distributed species, the inherent risk decreases from category I to category V.

The next step might well be to list actual (or perceived?) threats to a taxon. For example:

A. None;
B. Undirected, or unintentional killing (non-target species captured in gear set for target species; abandoned nets or snares; non-target victims of biocides);
C. Introduction of non-native species;
D. Introduction of a new disease/parasite;
E. Undirected human modification of habitats (acid rain and other pollutants);
F. Directed human modification of habitat (cutting forests, ploughing grasslands, draining wetlands);
G. Directed killing, sensu Holt. (Both legal and illegal).

Degree of threat could be added as a further refinement. Probably four subjective degrees would be sufficient:

0 = no perceptible threat,
1 = mildly threatening,
2 = moderately threatening,
3 = seriously threatening.

Finally, and perhaps of greatest importance, we must assess the response of the threatened taxon. If the danger comes from habitat loss, we may expect the *distribution* of the taxon to:

a. show no measurable change,
b. shrink,
c. become fragmented, or
d. become reduced to isolated pockets (= relicts).

If the threat acts directly on the taxon, we look for a second suite of responses, namely, *population* responses:

i. Show no measurable change;
ii. Numerical decline. Mortality exceeds natality. Initially we need only know (or strongly suspect?) that numbers are changing and that the direction of change is downward. Later it may be important to have an estimate of rate of change. Effort will be required, even to be able to say qualitatively that numbers are declining, (but very little that is worthwhile is accomplished without effort);
iii. The biology of the species is disrupted. Some of the symptoms to watch for are: distorted sex ratios, distorted age composition, social systems disrupted, seasonal cycles disrupted, individual growth and sexual maturation slowed, reproductive failures (King 1984);
iv. Intrapopulation genetic diversity threatened, or known to be in decline.

Many taxa may be faced with threats to both habitat and population simultaneously, in which case both categories of response would be indicated. A taxon would be classified by means of a series of symbols, much as foresters classify stands of trees. Whooping cranes, for example, would be classified as III f 3 d iv.

Note that the first three steps in this classification process require only qualitative assessments, and the fourth step requires little more. In that respect the scheme obeys the injunction of Norderhaug to 'keep it simple.'

Only step 5 requires some detailed knowledge of the biology of the taxon. Second, in a purely mathematical sense there are 2240 possible outcomes, but the number of biologically meaningful outcomes is much smaller. For example, it seems inconceivable that a widely and continuously distributed species, with no indication of a threat to its existence, could have it biology disrupted or its genetic diversity threatened. Similarly, if no threat has been identified, the degree of threat can only be 0. The still large number of possible outcomes, however, goes some distance in the direction advocated by Holt. At the very least, it recognizes that there is more than one road to extinction.

Even though the elements of the classification are largely qualitative, the assignment that results is largely objective. This is so because one can decide for the most part whether a taxon is 'social' or 'solitary'; whether it lives in a climax community or a successional one; which threat is most significant, and how serious any such threat is. But note that the classification proposed here does not contain categories such as 'threatened' and 'endangered.' To reach such a verdict requires that the classification of a taxon be interpreted. For example, 'endangered' might be defined as a rating of d for distributional response, or a iii or iv for biological response, regardless of the rating in other categories. On the other hand, a rating of c ii for response might be sufficient grounds if combined with a threat of seriousness = 3. At the other end of the spectrum, a threat of type A or B should be considered an early warning for taxa with a rank of I, II or III for original condition.

Management of Endangered Species

Management strategies should obviously flow from the category into which a taxon falls. If numbers are large, distribution is broad and continuous, and no threats either to the taxon or its habitat are detectable, then it is pointless to expend funds and effort on management. I suggest that management begins once a threat to a taxon's status is either observed (habitat destroyed by flooding), or perceived (proposal to build a dam). Furtado, in discussion, set out factors to be considered.

Road to Extinction

The usual first response seems to be to 'monitor', but just what is meant by 'monitoring' is seldom, if ever, made clear. At the very least, there must be an effort to document a change in either the abundance of a taxon or the extent of habitat suitable for it, or both, which may be what Sokolov means by 'improved prognosis'. If we cannot do even that successfully, I suggest that we cannot hope to do much to save a threatened taxon. A monitoring programme should also be able to identify the kind and severity of threats. To measure the response (s) of the threatened taxon is probably to go beyond monitoring to a full-fledged ecological study. Such a study will likely be impossible to mount for all but a few species, such as those that have 'megavertebrate charisma'.

In the end, positive steps may be necessary if a taxon is to be saved from extinction. The kind of action will depend heavily on whether the actual or perceived threat is directed narrowly against the threatened taxon alone (directed or undirected killing), or broadly against the ecosystem of which the taxon is a component (destruction of tropical forests, creation of a reservoir). In the latter case, the only chance of success is to preserve representative examples of threatened ecosystems; in the former legal sanctions, backed by adequate enforcement against killing and trade, may play a dominant role. Such sanctions and enforcement are obviously required even after national parks, or other special reserves, have been established, as experience with rhinoceros in south-east Asia has demonstrated.

Holt dealt *in extenso* with difficulties that stand in the way of protecting whale stocks. Without in the least denigrating those difficulties, I believe it is fair to suggest that whales represent something of a 'worst case scenario'. Even in the marine environment we have examples of successful conservation efforts (northern fur seals, gray whales, California sea otters). Even harp seals in eastern Canadian waters do not constitute as difficult a problem as the great whales. Harp seals are harvested under national, as opposed to international, jurisdiction; the harvest is virtually all confined to a limited area and a brief time span; and enforcement is rigorous.

When it comes down to habitat or ecosystem protection we must pay particular attention to studies such as those of Harris and Noss. It has become clear in the last decade or so that we should not be thinking of individual parks and reserves in isolation, but of *systems* of reserves, carefully chosen to form functional 'archipelagos'. At this stage megavertebrates or flowering plants may be the focus, but our efforts to protect those taxa will also benefit lesser members of the fauna and flora, including decomposers.

The ultimate management device would seem to be captive breeding, aimed at retarding the rate of loss of genetic diversity to the greatest extent possible. This topic was not specifically addressed in the symposium.

Legal Implications

Bean warned us that categorization tends to 'trigger only limited prohibitions on hunting and trade', and may, in addition, have quite unexpected results. An important failure of much legislation is that it is framed 'in the negative, prohibiting hunting and trade, but ignoring altogether the more subtle and insidious factors contributing to the decline of many species'. Laws are clearly needed that provide a legal foundation for 'affirmative programs of conservation'.

In the discussion Bean, de Klemm, and Burhenne all made the essential point that 'no immediate legal consequences flow from conservationists' categories'. Burhenne further pointed out that legal categories must describe an effect, such as 'decline', or 'extinction'. To that extent, they contain a dynamic element as opposed to a simple static classification.

Finally, to be useful in law, categories must be carefully defined, unambiguously if possible. If the road to extinction is a continuum, that would amount to setting rigid arbitrary limits, to which Holt, rightly in my view, objected. If, however, we recognize a network of roads to extinction in hyperspace, we need Holt to tell us whether we can define, at a pre-determined level of probability, a volume within that hyperspace that is unfavourable to the point of endangerment. Alternatively, might the five-point scheme I outlined above serve the purpose adequately?

We cannot leave the present topic without recognizing, as Bean said, 'that designation can focus increased interest on the species by unscrupulous collectors and traders', and put roadblocks in the path of legitimate and necessary research.

Recommendations

The following suggestions deal with two recurring problems: the three reasons for categorization put forward by Holt, and the need to place more emphasis on plants.

Entity of Concern

Arguments have been presented to the effect that the Linnean species, an infraspecific category, or even the population, ought to be the level of concern. Surely there can be no hard and fast rule on this score. The decisions must be made after taking into consideration the state of the whole system along the lines suggested by the 7-point key at the beginning of the paper.

My feeling is that on the global scale, the level at which the SSC operates, the Linnean species is the 'natural' unit of primary concern because it has a unique, internationally recognised name, is considered to share a common, but unique, gene pool, and most biologists have some feel for what is meant by a 'good' species. However, if the range of the surviving members of a threatened species is fragmented it may make good sense to deal with smaller units. At the national level I would expect the level of concern to be an infraspecific category in most cases, because it is relatively uncommon for a single nation to encompass the entire range of a species. A nation may wish to protect a single population of a species that is considered to be in danger within its borders, though not globally.

There is another side to this question, namely that no species, subspecies, or population exists in isolation. Each exists as part of a community within an ecosystem, and it is only on this 'ecological stage' that the 'evolutionary play' can be acted out properly. Therefore, we should never lose sight of the need to preserve the entire community of which a threatened taxon is a member whenever it is possible to do so.

The Question of Numbers

Although there was a general feeling that numbers alone are of limited value in establishing categories, there are some counter arguments. First, the entire scientific enterprise is based on quantification - counts and measurements. Second, maintenance of genetic diversity is a function of effective population size (Ne). Third, extinction itself is unambiguously defined by the number 0. As conservationists make more use of scientific principles, such as the population genetics of scarcity and the theory of island biogeography, they must be willing to devote the effort and funds necessary to obtain the required numerical base. Obviously, as a taxon slips closer and closer to extinction the need to quantify becomes more and more pressing.

One way to reduce the impression of unwarranted precision of a census estimate (n) is to publish the result as a common logarithm (logl0(n) or log(n) to no more than one decimal place. For example, a census estimate of 2 million (for harp seals, say) becomes 6.3 on the log scale. But 6.3 can be interpreted as a value betwen 6.25 and 6.34, or in numbers, between 1.178 and 2.188 million. The ratio of the upper limit to the lower limit is 1.230, which is a range of 23%. It can easily be shown that the same range of uncertainty holds for every value on the log scale. If n.x means n.(x-.05) to n.(x+.04) then the difference between upper and lower limits will always be 0.09. Since the difference between two logs is equivalent to the ratio between the corresponding numbers, the ratio will always be 100.09 or 1.230. Furthermore, although the relative error is constant, the absolute error diminishes with decrease in both the characteristic and mantissa of the log. Thus at n.3 the range is 0.4095 x 10n, whereas at n.7 the range is 1.0286 x 10n.

Any number of conservation interests can be expressed on a 10-point scale running from 0 to 9. The definition of 0 (log(n) when $n = 1$) could be extended to mean log(n) where $n \geq 1$ since organisms come as integers and $n = 1$ means extinction for a sexually reproducing species unless the lone survivor is a gravid female. The definition of class 9 could also be extended to mean log(n) when $n \geq 109$.

The Public Relations Function

Holt laid considerable stress on the importance of this function, and his view was echoed by Norderhaug in the discussion. A way must be found to display the status of a species so that it is readily understood by the general public. An analogy with another familiar phenomenon, or adaptation of an instrument that is in common everyday use, immediately comes to mind. Thermometers must be among the most commonly recognized instruments everywhere in the world. Measurement scales, on the other hand are far from universal. Let us consider two common phenomena - wind speed and earthquakes. The Beaufort Scale for wind speed illustrates that a useful scale can be constructed that uses only qualitative parameters. The magnitude of an earthquake, on the other hand, is reported on the logarithmic Richter Scale, and it seems to make little difference that many people, perhaps most, do not fully appreciate the significance of the latter. So why not a scale in the form of a thermometer with gradations running from 0 to 9 to represent the position of a taxon on the road to extinction? The fact that the scale is logarithmic need not be emphasized; only the integers need be shown on it. Portions of the scale could be coloured (red for 'endangered', orange for 'threatened' or 'vulnerable', green for 'no danger' or 'out of danger') to enhance the effect. Interpretation of the scale could vary for commercially exploited species and those not so exploited.

Such a scale could be referred to as the 'Extinction Scale' if the imminence of extinction were the focus, or the 'Conservation Scale' if the positive effect of human intervention were featured. This proposal is elaborated in the note on below. Another symbol, which would be instantly recognized in North America at least, is the sort of device used to rate forest fire hazard using several colours.

Classification for Legal Purpose

It is clear from Bean's paper and the remarks of de Klemm and Burhenne that, to be useful to lawmakers, categories must be as unambiguous as it is possible to make them. Criteria must be clearly stated so that taxa may be classified, or reclassified on the basis of new data, with a minimum of argument. In the case of a scheme such as that presented, the interpretation of any final outcome is straightforward, but subjective decisions must be made along the way, for example, in using the key and in assessing degree of threat. The problems are reversed if numbers are used as the only criteria. A census result may be quite unambiguous, but that result may be open to different interpretations. For example, de la Mare suggested that harp seals, with a population of between 1 and 2 million, ought to be treated as 'threatened'.

Bean also argued convincingly that there is no point in establishing a plethora of categories. Clearly, we need a category 'endangered', and a warning category such as 'vulnerable' or 'threatened'. 'Endangered' could be defined clearly on the basis of combinations of features. It seems to me that it could also be defined quite rigorously in terms of some multiple of the best possible estimate of Ne. Exactly which multiple is chosen is probably less important than achieving unanimity. However, unanimity is probably not so important in establishing a criterion for 'threatened'. 'Endangered' should certainly be enshrined in the law, but I am not convinced that the same is true for 'threatened', even though it may be a useful category for conservation strategy and management planning.

A very important point made by Bean is that, if categorization leads only to prohibitions against taking or trade, or both, it has limited value. I fully endorse his plea that conservationists should press for 'more broadly stated authority to carry out affirmative conservation programmes to aid their recovery, entailing not only the regulation of hunting and trade, but also the management of other activities affecting the species or its habitat'.

Classification for Management

The initial decision that a taxon is 'threatened' may be based on an observed numerical decline, a decrease in occupied range, identification of a new threat, intensification of a pre-existing threat, or some combination of warning signals. However that decision is made, it should be the signal to begin positive management. (The term 'monitor' is often used, but the action required goes beyond 'admonition', 'keeping order', and 'reporting'.) Population status and dynamics, details of distribution, and information about the nature and severity of threats should all be documented as quantitatively as possible. At the very minimum a concerted effort should be made to determine at least the direction of numerical change, if not its magnitude or rate. The next step is to obtain the details of basic biology required to estimate Ne (sex and age ratios, details of reproductive biology), assuming that the designation of 'endangered' will be based on Ne in the final analysis.

National governments must be urged (bullied if necessary) to respect the designation 'endangered', and to pass legislation that will enable both negative (e.g. prohibition of killing) and positive (e.g. establishment of reserves) steps to be taken without further delay. Plans should also be made for intensive management in captivity should that become necessary as a position of last resort.

Plants

The Symposium papers, and these comments, are heavily weighted toward the conservatiion of animals. Although there are many similarities in the basic biology of plants and animals there are also many important differences. Clearly, the SSC must devote more of its attention to exploring the meaning of those differences. It seems entirely possible that separate criteria may be required for the two groups, and possible also that separate but parallel legislation may be unavoidable.

AN EXTINCTION SCALE

My primary assumption is that the first function of a system of categories is to serve as a *warning system* - preferably an *early warning system* - that a species is in trouble. It may also serve as a guide to the application of increasingly more sophisticated management procedures; it may be adopted by law-makers, and it may serve still other functions. Secondly, for the purposes mentioned I believe the initial categorization should be simple. We should be able to ring the first alarm bell without waiting for 'hard' data. A third point is that any system should be quantitative to the greatest extent possible, which may well bé less than 100 percent. However, in many respects, great precision is not required.

These comments rule out a *fully* qualitative scheme, although there may be qualitative elements. They also rule out the Holt proposal *as an early warning* system, but I suggest a possible function for it below.

The alternatives, therefore, come down to a system based on absolute numbers or relative numbers. Munton (Chapter 9.) refers to a relative-number system - ratio of current number to initial abundance. This is simple, but probably fails on two counts: initial abundance is not likely to be known, and, given different initial numbers for each taxon, the absolute abundance at any arbitrarily chosen number, say 10 per cent will vary greatly.

Natural numbers also have their pitfalls - the range is too great, and they tend to imply considerable precision. Faced with a broad range to encompass, the physicist uses logarithms. Log transformations are second nature to demographers, since populations grow exponentially, and declines, too, are often exponential. If we can detect that the rate change in either direction is approximately exponential, we can use another property - constant doubling time and half-life so long as the growth rate is constant. That property makes rough and ready prediction rather simple. Finally, if we express the log 10 to only one decimal place, we do not imply great precision for the larger numbers, which are the ones we will never know precisely.

I therefore propose an *Extinction Scale* running from 0 - 10 in log 10. Zero would be defined as $n \geq 1$, and 10 could be defined as $n \geq 10^{10}$.

Several other points need to be addressed:

1. It is implicit that the parameter of primary interest is abundance, or number of individuals in a taxon.

2. In general, the taxon of concern will be a Linnean species. An enormous advantage of using the species is that it has a unique, internationally recognised name (subject to the vagaries of codes and commissions). There is no reason why a subspecies, or a supra-specific grouping could not be used.

3. The parameter of secondary concern is pattern of distribution. If a continuous distribution pattern becomes fragmented, the unit of concern should shift from the species level to the population level. If a species has two or more disjunct populations when it first comes to the attention of the SSC, concern should lie with the population from the outset.

4. Different 'alarm levels' may be required for species under commercial exploitation than for those not so exploited.

5. 'Alarm levels' (= categories), should bear some relationship to a unit we might call a 'minimum population' (N min). N min would be defined as Ne (in the population genetics sense) plus associated individuals in the population. N min might be of the order of ZNe. If no observed value is available 2 Ne could be used as a first approximation.

6. Ne would probably be based on acceptance of 1 per cent of genetic variability per generation. It would be important to know the sex ratio, less important to know the family size or amount of genetic exchange with nearby demes (if any). Ne would likely lie within the range of 50 to 500 individuals.

7. Time may be, or become, 'of the essence'. The biological time of interest might be observed, or estimated half-life, the length of a generation, or some compound measure. It would need to be compared with an estimate of 'political action' time to evaluate the seriousness of the situation for a given taxon.

How it might work

Classes 7-10 would include initial numbers for a great many species. We do not need to specify initial numbers in any detail, but an upper limit could be indicated in text or on the Extinction Scale. Differences in estimates would be smoothed out. For example, Setou's estimate of pristine numbers of *Bison bison* (75,000,000) and mine (15,000,000) would both be in the range of 7-8 on the scale.

Class 6± might well represent an early warning level for commercial species. De la Mare suggested that harp seals at N 10^6 x 2 (= 6.3 on the Scale) may be threatened. Reliable census data is the minimum requirement at this stage. Class 5 would also be a warning level for commercial species, particularly those whose stocks may never have exceeded 10^6 (large mammals ?) and for those known to have declined from Class 6 to Class 5. Class 4 warning level would be for species *not* subjected to commercial exploitation (as well as those that are).

By this level we clearly need information on basic biology - age and sex structure, details of reproductive output, mortality factors, migrations and so on.

The term 'threatened' might, therefore, be applied to classes 4, 5, and lower 6. Since the term is in wide use, it might be well to retain it. Class 3± could well be the upper boundary of the category 'endangered'. At this stage we can count the number of minimum population units (N min) on our fingers. We now require more than information, although we can never have too much of that. Reserves may be essential. Captive stocks may be a wise investment. Legal protection (complete prohibition of killing) should be demanded (if not already in force).

Class 2. We are down to about N min under the most favourable conditions. 'Hervie' measures are required, and should be directed toward rapid recovery from the genetic 'bottleneck'. The needs are total protection of species and habitat, probably in reserves, combined with a captive breeding programme if the species will breed in captivity.

Class 1. Captive breeding may now be the only thing that can save a species, even temporarily, from extinction.

The Holt Plan

If a simple early warning system functions as it should, and if nations, or the international community respond as they should, useful information should begin to accumulate. The kind of information required should be specified (by the SSC?), and should include information about threats to survival, threats to habitat, role of associated species, etc. The data so obtained could well be planned to be compatible with a multivariate analysis, as suggested by Holt.

THE PANEL DISCUSSION

After the six presented papers and the summing up by Dr Fuller, the Convener called on the members of the Panel to make their contributions. Later, some Panel members and other discussants elaborated their remarks into short papers, which are printed at the end of this report.

Dr J.I. Furtado addressed the specific problems of categorising species status in tropical ecosystems. A short paper based on these remarks appears later.

C. de Klemm asked whether status-based categories can ever be accurate. The European Law Commission (ECL) examined many legal systems and found very few status-based categories; most are based on law, such as control of activities, special penalties or special protection. It is not only protected species that are endangered; there are many other categories that are endangered; there are many other categories, such as game species. Many legal systems have reverse-listing, i.e. they specify the species which are not protected. Red Data Books are indicators, not only of species for listing or positive management, but of other groups too. They are important because legislators need precise and accurate information.

M. Norderhaug, speaking from a European viewpoint, said that the Symposium had demonstrated both that this was a complex problem, and that it needed a simple approach. Listing is a tool not a goal, and must be easy for both politicians and the public to understand as well as use. He suggested that IUCN's present categories should be broadly maintained, since big changes lead to confusion and do not help conservation. The SSC should examine the present categories with a view to small necessary improvements, and should draw up Red lists, revising them on a continuing basis.

Arne Schiøtz addressed the biology of extinction. His remarks are detailed at the end of this chapter.

Dr Michael Tillman said that categorisation is an important aspect of the Conservation Monitoring Centre's activities. Though CMC researchers receive subjective estimates of species status from many field workers, they would be happier to have quantitative data. Paul Munton had suggested that estimates of population size and rates of decline were desirable, but these were most difficult to obtain. As in whaling, commercial operations can deplete stocks quicker than scientists can discover they are doing it. Therefore subjective evaluations have their place, but should not be inflexible.

The Convener then opened the meeting for general discussion.

W. Burhenne (Chairman, IUCN/CEPLA) pointed out that there were no common standards, the status allocated to species varying, according to circumstances, at regional, national and international levels. However, law is absolute and does not recognise anything but its own consequences.

Dr M.P. Nayar (Director, Botanical Survey of India): Though we know that any classification of a biologically evolving system is unscientific, Linnaeus's species concept has come to stay, and the categories used in the RDBs are a useful tool and a bench-mark for conservation and further research; to change them at this stage would create confusion, especially in developing legislation. Ideally one should wait for detailed multidimensional concepts and population studies, but if we do this, many species will become extinct. What we need is field or 'fire-brigade' action. The Department of the Environment of the Government of India has set aside a large sum to establish tissue cultures and seed banks of endangered species.

Dr Martin Angel (IUCN Ecology Commission; Institute of Oceanographical Sciences, Wormley, UK): So far the discussion has missed the concept of time-space variability. On the time scale of eternity, all species will become extinct. However, on the time scales of individual life histories, the probability of extinction varies. Thus an endangered species is one with a high probability of extinction within the lifetime of existing individuals. The probabilities are also subject to climatic variability and catastrophe, and to being speeded up by man. We can only control the man-made aspects of catastrophe. Any categorisation must take account of these probabilities so that management and legislation can reflect these changed probabilities for any species.

Professor Laurence Roche (Department of Forestry and Wood Science, University College of North Wales, Bangor) spoke on the problems of conserving endangered tree species. His remarks are elaborated in a short paper later in this Chapter.

Dr L. Harris stressed the importance of co-ordinating development plans with conservation plans. Many species have too extensive a range to be contained within national parks, so a modular approach is necessary.

Richard Fitter (Chairman, Steering Committee, SSC; Chairman, Fauna and Flora Preservation Society, London) took up the point that we cannot afford to lose any species by citing the example of the smallpox virus, for which genetic engineers have now found a use. An additional problem arose when only one sex of a species survived, as with the dusky seaside sparrow *Ammodramus maritimus nigrescens* of Florida, of which only males now survive, and the aberrant New Zealand parrot, the kakapo *Strigops habroptilus*, which until recently was feared to be in the same plight. We had to accept that all categories are artificial and are part of a complete continuum between abundance and extinction.

Dr Thomas E. Lovejoy (Vice-President for Science, WWF-US), as an early advocate of triage (giving priority to species thought most likely to be saveable), now felt that it was only a workable solution in captive propagation of both animals and plants. More species could now be maintained in zoos than ever before, and the genetics of small populations may be less of a limiting factor than was once thought. Triage in the wild is more difficult, especially if the ecosystem approach is adopted. The only effective answer to lack of resources is to concentrate on centres of endangerment. Even so, conservationists have to take care to explain themselves to the public, so that neglect of certain endangered species is not seen as lack of concern.

Professor Vernon Heywood (Chairman, European Plants Group, SSC; University of Reading, UK) spoke on the problems of categorising plants. His remarks are elaborated below.

Dr Mateo I. Margarinos de Mello (Centro de Invest. y Promocion Ecologico y Transciscano, Montevideo, Uruguay) was sorry to see no Latin American speaker or panel member. He pointed out that the global problems of extinction and depletion are holistic, and must be tackled as a whole. The only way to stop illegal trade is from the end of the line, in the consumer countries, which provide the incentive for poaching and smuggling. The countries of origin are largely helpless while demand from the developed countries is so strong.

George Rabb (Member, Steering Committee, SSC; Director, Chicago Zoological Society, USA) urged that prime attention should be given to 'keystone' species, such as reef corals, and the army ants in the forest islands of Amazonia on which whole assemblages of insectivorous birds depend. He also drew attention to work on mass extinctions by David Raup and others, which suggests that species died in cohorts even between such mass-extinction episodes as the one on the Cretaceous-Tertiary boundary when the dinosaurs died out. The parallel with the collapse of complex ecosystems today suggests that if we do nothing about these collapses, the already predicted mass extinctions may occur. If they do, the cause will certainly not be extraterrestrial. He recommended the

SSC to promote and encourage research into the biology of extinction, as a vital element in the setting of conservation priorities.

Robert F. Scott (Executive Officer, SSC) suggested that species likely to be abandoned for lack of funds should be 'offered' for fund-raising.

Richard Fitter discussed the problems of determining pristine populations, with the following examples: (1) the northern right whale *Balaena glacialis*, whose pristine population only existed before its commercial extinction in the Middle Ages; (2) the azure-winged magpie *Cyanopica cyana*, now found only in the Iberian peninsula and the Far East, which must originally have had a population in between; and (3) the cruciferous plant *Sisymbrium irio*, now found only in two spots in London, which was widespread there after the Great Fire of 1666. How does one determine the pristine population of ruderals? Go back to the aftermath of the Ice Age?

Dr Ian F. Spellerberg (Chairman, Environmental Sciences, Southampton University, UK) said that Dr Fuller's proposal seemed very logical and well thought through. However, it relied on a great deal of data on population levels, and there are many animals for which total populations cannot be calculated. For these instances it may be possible to monitor change, either by using some kind of index or through changes in the patterns of distribution, such as reduction or fragmentation in total area.

He also pointed out that, for good reasons, endangered species lists in legislation differ considerably from those in national RDBs. However, it would seem sensible for legislators to be made more aware both of the existence of the RDBs and of the nature and value of the information they contain; they should also be encouraged to make more use of them in drafting and developing legislation.

M. Norderhaug stressed the need to pay more attention to population trends rather than to the ratio between the actual and original population size. Trends are easier to identify and describe, as indicated in Fig. 1.

Imre de Boroviczeny (Chairman, ICBP Spain) said that habitat change and destruction many and sometimes do influence populations some time after their actual occurrence. Thus a merlin *Falco columbarius* population in the UK crashed two years after its habitat changed. Habitat change should be considered in forecasting threats and early classification of a species as threatened.

J.M. Knowles (International Union of Directors of Zoological Gardens; Marwell Zoological Park, Winchester, UK) mentioned the need, with all categories, to make clear what the captive population is, including its genetic and demographic profile. These facts are increasingly known from studbook and ISIS (International Species Inventory System) species. Endangered and extinct species are available for reintroduction into the wild in substantial numbers from captive stocks, and this knowledge needs to be widely available.

I de Boroviczeny said that to create greater awareness of the significance of extinction and depletion among both policy-makers and the public, the consequences of the extinction or severe depletion of one species on other species in the same habitat or ecosystem should be made clear. Since many people are quite uninterested in wildlife, the practical and if possible monetary value of species and the implications of their extinction should be stressed.

Dr Russell A. Mittermeier (Chairman, IUCN/SSC Primate Specialist Group) thought we should stick with the existing categories in the RDBs, but refine their definitions. Most of the information now being discussed is already on the RDB sheets, but not in the definitions, which are very weak.

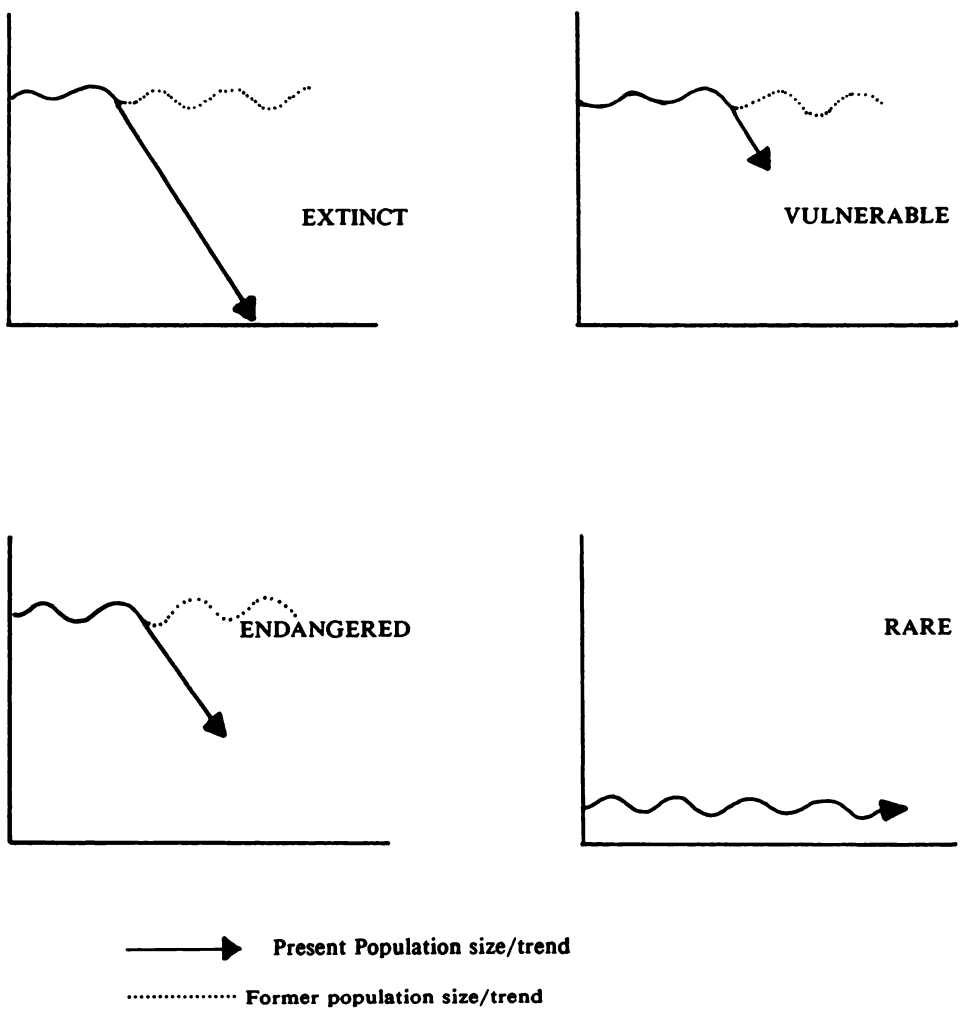
George Rabb recognised that IUCN must itself be able to assess confidence in the objective evaluations used in categorising species. He therefore supported the idea of utilising of data on the status of endangered species in a compound way to achieve higher levels of confidence in the process of categorisation. He cited a parallel in character analysis in taxonomy, where discrimination of relations between taxa could be improved with progressively greater levels of information on relations of character states, but one could still operate in discriminating at lesser levels of information and therefore of confidence.

In earlier SSC sessions he had pointed out that any serial classification with dependency between successive classes produced an automatic weighting, and that any weighting must reflect the general balance we wished to have between biological values and man-induced endangerment values.

I. de Boroviczeny suggested that the RDBs should stay as they are at present, as they are often used by non-experts, but that traditional data sheets, uniform if possible, should be prepared, not for general publication but for use when fuller or more exact data are needed.

E.R.C. Davidar (Hon Consultant, SSC, Madras, India) said that in categorising species, captive-bred as well as wild populations should be taken into account. For example, the mugger or marsh crocodile *Crocodylus palustris* population is low in the wild but abundant if the captive stocks are included. The RDBs are often taken as a guide in framing national legislation and this may stand in the way of any culling which may be necessary in the interests of the preservation of the species.

Fig. 1. Simplified/Educational Presentation of IUCN's Main Red List Categories



Magnar Norderhaug (1984). Ministry of Environment. Norway.

SOME PROBLEMS

J.I. Furtado

The Symposium papers have demonstrated that categorization of species status in relation to extinction is useful, is still in its infancy, and must be simple for legal and implementation purposes. These categories have evolved as a result of man's relatively recent preoccupation with dominant and spectacular species.

In the main the categories have been developed for two purposes: (a) for management of resource stocks (e.g. whales), and (b) for protection of rare, threatened or vulnerable and endangered species (e.g. Red Data Books). While these categories are inevitably subjective, it appears necessary to develop them scientifically in relation to species status and evolutionary and extinction biology. This is possible if one uses case studies in population and applied biology, besides other theoretical studies. Needless to say, the species status is affected by the species concept utilized, whether typological or Linnean and multidimensional.

The survival or extinction of any species appears to be governed by three main factors (or vectors): (a) biotic potential including natality or mortality, which will vary according to species and according to their k- or r- strategy; (b) aggregation or patch habitat and ecosystem size which varies according to biophysical factors; and (c) biotic or interspecies and symbiotic interactions or linkages. Only 10 per cent of the total species on this planet have been authenticated over two centuries; the majority of species, therefore, which are in the tropics and mainly animals, do not seem to have the prospect of being authenticated in the near future unless new and rapid assessment technology is developed very quickly. The study of biotic potential for categorization purposes is thus not a practical proposition for tropical species. Furthermore, most species in the climax phase of tropical forest ecosystems appear to have a k-strategy which makes them vulnerable to perturbations.

Very little is known about species aggregation or patch, habitat or ecosystem size especially for tropical species. It is well known that tropical species have a patchy distribution, and a variety of mechanisms to prevent in-breeding even when populations are aggregated. Furthermore, space is highly differentiated into biotopes or habitats in the tropics by physio-chemical and biological factors. Since this factor cannot be used effectively to categorize species, especially in the tropics, protection of representative samples of ecosystem types of large and stable size appears the only practical approach for the conservation of tropical species.

Biotic interactions have been poorly studied hitherto, and are particularly important in the tropics, where the ratio of plants to animals is about 1:6. Thus interactions may be trophic, parasitic or symbiotic; they may concern specific dependence for pollination, habitat selection or reproduction; they may involve migratory species, alteration of generations or fluctuations and interactions at the land-water interface. The importance of this factor in the tropics is illustrated by the destruction of 70 per cent of the forest structure with the felling of one dominant tree per 1-2 hectares; by the abundance of rare species; and by the reduction of species diversity by one order of magnitude (from 120 to 10-12 species) in freshwater fish when inundated forested swamps are transformed into simple wet rice fields.

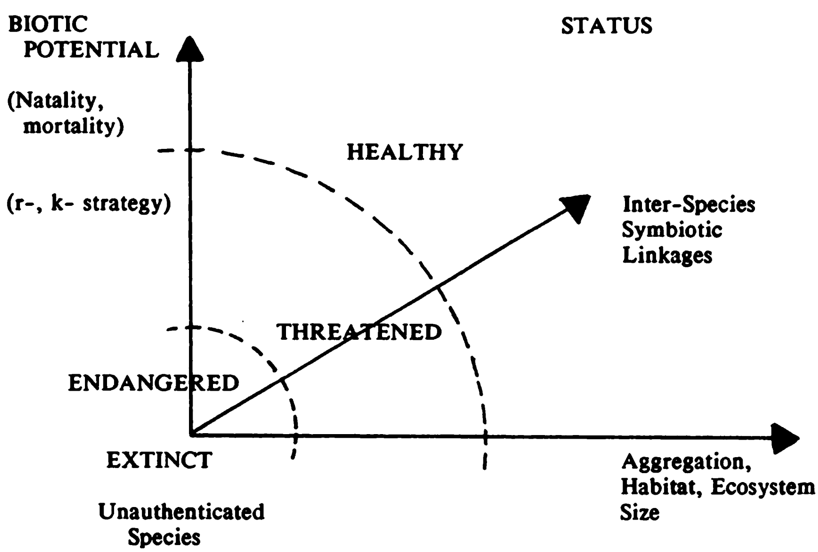
Biotic potential, habitat or ecosystem size and biotic interactions are affected by two main groups of factors; (a) direct population impacts such as harvests by man and predation or parasitism by other organisms, which affect natality and/or mortality and life-span; and (b) indirect population impacts such as pollutants and habitat transformation or destruction.

The status of a species may be further assessed by a variety of indicators such as: (a) genetic variability at the intraspecific and transpecific levels; (b) rates of population increase or decrease; (c) spatial heterogeneity indicators; and (d) diversity and flexibility of biotic interlinkages, of which species diversity is an index.

On the basis of the three main factors, at least, the topology of a multidimensional graph may be constructed to provide some sound and useful models for refining the categorization of species in relation to the biology of extinction. The shape of this graph would at least be a spiral staircase fluted on the outside. In phylogeny, however, there has been considerable uncertainty as to survival because natural selection is a stochastic process. Species categorization must therefore incorporate some margin of flexibility to accommodate for this uncertainty.

In conclusion, while simple species categorization is important for protection purposes, there is an enormous challenge ahead to refine this categorization with respect to the biology of extinction, especially the three factors of biotic potential, habitat or ecosystem size and biotic interactions or interlinkages.

Fig. 2: Interrelationship between biotic potential, habitat or ecosystem size and biotic interactions or interlinkages with respect to the purpose (or criteria) for categorization, impacts on species populations and indicators of species status.



CRITERIA	POPULATION IMPACTS	INDICATORS
1. Species Status	1. Direct	1. Genetic
2. Management	2. Indirect	2. Population
3. Protection measures		3. Spatial
		4. Interlinkage

SURVIVAL Uncertainty + Stochastic processes

PLANT POPULATION BIOLOGY AND CONSERVATION

V.H. Heywood

For most of the SSC's history attention has been focused primarily on animal species. This is understandable, but it has led to the development of conservation strategies based on what we know of the functioning of animal populations, and it would be wrong to assume that such strategies are equally applicable to plant populations.

The relationship between plants and animals in conservation biology is enormously complex, the point of departure being the underlying fact that for most animal groups plant life forms a major and essential part of their habitat as well as their direct or indirect energy source. Just how neglected even this aspect may be is only beginning to be realized with the studies of Erwin (1983) suggesting that the numbers of insect species inhabiting the canopy of tropical rainforests are very much greater than suspected, even if his figure of 30 million is considered excessive. Likewise, our understanding of the multifarious plant-animal interactions in such forests (or indeed in other habitats) is still very incomplete and limited (see, for example, papers and abstracts in Chadwick and Sutton, 1984).

Plant and animal populations differ quite significantly in their structure and function. The purpose of this note is to draw attention to some of the more salient differences in the hope that more attention will be focused on them, so that relevant models and policies for the conservation of plant populations can be formulated, and to draw attention to the need for all plant conservationists to take greater heed of the work that has been done on plant population biology and demography in the past two decades, much of which is relevant to the practical problems of conserving plant populations.

The following summary is in no way comprehensive. In addition to the main points noted there are probably many that have not yet been appreciated or adequately documented, and certainly there has been too little intellectual input from plant conservationists in this critical area, much work 'on the ground' being pragmatic, superficial or even downright unscientific.

As Harper (1977) in his classic monograph *Population Biology of Plants* comments, 'There are fundamental parallels between the population biology of animals and plants but the differences are sufficiently great that it can be dangerous to generalise from one kingdom to another without recognizing the differences'.

Population biology of plants is a rapidly developing area. It was not until the last decade or so that attempts were made to apply a demographic approach to the study of plant populations, hitherto a subject considered to deal with only human or animal populations (Baker 1980). Until then, our knowledge of the age or size structure of plant populations and our frequent inability to explain individual variance in their vegetative and reproductive performance was very limited and patchy (Sarukhan 1984).

Mobility

One of the most obvious differences between plant and animal populations is, of course, their mobility or lack of it. Higher plants are non-mobile and dependent on the elements or animals for dispersal of pollen, seeds or other propagules. As Sarukhan et al. (1984) put it: 'Plants not only stay quietly in one place to be counted and measured... as they grow, reproduce, and die; they are also endowed with the ability to grow, reproduce, and die at rates that vary widely among individuals within the same populations'.

The fixed, rooted habit of most plants prevents them from moving about in search of the limited resources available and escaping from their neighbours. The clumped distribution of plant populations often results in some members being under stress caused by density, even though adequate resources may be available nearby but inaccessible to them (Harper 1977).

Life Cycle Strategies

Higher plants have life cycles, with an alternation of generations. Solbrig (1980) divides the life cycle into the following five phases which is useful for conservation purposes:

1. *pre-dispersal* (from fertilization to seed release) when the new plant is still dependent on the mother plant;
2. *dispersal phase;*
3. *germination and establishment phase*, from germination to the reproduction of the first pair of true leaves;
4. *adult stage*, including both the pre-productive and reproductive adult;
5. *flowering, gametogenesis and fertilization.*

As he points out, if we are to understand the dynamics of the population and the community, then it is crucial for us to unravel the various stages of the life cycle.

Modular structure - Plants as populations of parts

Harper (1977) draws attention to the concept of the population-like structure of the individual plant:'A plant is a population of parts that are born and die at different times' (Harper 1984). Plants are made up of modular units of construction - leaves, flowers, seed, etc. and for some purposes the population dynamics of the individual parts may be more useful than the dynamics of the individual whole plants in the community. Because of the individual plasticity of plants - often within very wide limits - it is of little value simply to count plants in a population unless information on their size is also recorded. See also the reviews by White (1980, 1984).

Reproductive Biology

The modular construction of plants leads to great variation in fecundity - in the number and phenology of the reproductive organs and versatility in the sexual expression of angiosperms such as pollen/ovule ratios (Cruden 1977). Also, sexual or vegetative replication or reproduction presents a number of both theoretical and practical problems in plant demography that are relevant to conservation biology (Abrahamson 1980).

Other features of reproductive biology that have no direct parallel in animals include seed dormancy and the seed bank (the number of viable buried seeds in the soil).

Agamospermy

This is a special kind of asexual reproduction which serves as a substitute for sexual reproduction by seed. It may be facilitative or obligate and especially when associated with polyploidy and hybridization it leads to complex situations in terms of taxonomy and population structure.

Polyploidy

It is estimated that polyploidy has been involved in the origin of about half the species of flowering plants. There is no parallel to this in animal groups. Polyploidy affects population biology, structure and evolution in many ways, some obvious, others not so apparent.

This high incidence of polyploidy, together with the more localized gene flow found in plants compared with animals, affects the pattern of genetic divergence in plant populations in a much more marked way than in animals (Liv & Godt 1983).

Population size

In terms of conservation, the differences between plants and animals that we tend to be concerned with are those that apply in situations where the populations, for whatever reason, are small in relation to their original size, i.e. how does population biology affect the survival of small populations?

It may well be that in many cases, small plant populations have a better chance of survival than do small animal populations and this despite (or possibly because of) the lack of mobility of plants except through their pollen or seed. This is also likely to be affected by the eco-climatic conditions in which the plants grow. There is clearly a difference between, say, populations of species in a humid tropical forest and those in a Mediterranean matorral, in terms of numbers, distribution pattern, reproductive biology, etc. And again, differences in habit as well as habitat, are significant. The methods of population biology, notably those of population dynamics that have been conventionally applied to annual or perennial herbs, can only, with difficulty, be applied to trees.

It is hoped that this very inadequate summary will draw the attention of conservationists to the need to devise an adequate plant-oriented approach to the study of plant populations and not only on models and approaches borrowed from animal population biology.

Acknowledgements

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CONSERVING ENDANGERED TREE SPECIES

Laurence Roche

Almost all tree species studied to date exhibit habitat-correlated, genetically based variation. When the species is distributed over a wide range of environments, variation within species is often very great. It is this variation, referred to as the genetic resources of the species, which is the basis of evolutionary development, and the starting point for selection and breeding programmes.

Such programmes are virtually non-existent for tropical trees, the few that have been started are in the early stages, and, with the exception of long established programmes for such tree species as *Hevea braziliensis* (rubber) and *Elaeis guineensis* (oil palm) and more recently those for some species of tropical pines and eucalypts, few have received the resources necessary to allow rapid advances in the species' genetic improvement. This situation is not likely to change significantly between now and the year 2000. Meanwhile it is certain that the genetic resources of tropical and subtropical tree species, particularly those of semi-arid and mountain regions, will be continually eroded. Furthermore, these species are often the ones of greatest value in providing food, fodder and fuel to rural peoples.

Little is known of the genetic resources of tropical tree species, at least to the scientific world, but local people, culturally and economically dependent on natural forest resources, are often extremely knowledgeable about the values and uses of variable forms of a single tree species. This knowledge is for the most part untapped by conventional forest research. Such studies as that of Getahun on the role of wild plants in the native diet in Ethiopia, and Okafor's account of edible indigenous woody plants in the rural economy of the Nigerian forest are as rare as they are important.

In this situation it is obvious that conservation effort must for many years be directed to the level of species and ecosystems rather than sub-specific variation. In the process, however, genetic resources, often unknown as to their potential, will be conserved.

THE BIOLOGY OF EXTINCTION

Arne Schiøtz

Extinction is the death of a taxon. Like the death of an individual, it is part of the natural life processes. To examine this natural process has some merit, especially if one intends to influence it. However, this is not such an examination but merely an attempt to systematize some of the relevant factors.

Natural Causes of Extinction

A. Species senescence.
B. Competition.
C. Predation.
D. Parasitism and disease.
E. Isolation.
F. Habitat alteration.

All these factors have been debated extensively in the literature, and there is considerable discussion about the validity of some them, e.g. species senescence, and how far competition, predation, parasitism and disease do in fact lead to extinction. Extinction through isolation, as on islands, is well documented through biogeographical studies, and so is extinction through habitat change of geological or climatic origin. But all these natural causes are insignificant compared with man-made causes. It is doubtful whether any species has become extinct for these reasons within the last few centuries.

Man-made Causes of Extinction

The impact of man on extinction seems to be orders of magnitude higher than the impact of nature.

Overexploitation. This is well documented, with many case studies, from the fate of the dodo to advanced mathematical treatments of modern whaling and fisheries. In many cases overexploitation is of such a nature that it will lead not to the extinction of the species but of the trade, leaving renmant populations that may survive.

Deliberate extirpation. Many species have been hunted, not for exploitation but to be wiped out, as pests. This has been official and unofficial policy in a great part of the world, and is still so today in many places. The public outcry when a wolf is discovered in Norway is a case in point. It is probably sobering to realize that even today people trying to prevent extinction or extirpation are normally an esoteric minority.

Habitat destruction and degradation. There are surprisingly few well documented cases of habitat destruction or degradation leading to extinction of species, but it seems likely that it will become the major factor in the next century. Figures for species extinction due to tropical-forest degradation are not based on firm data and are highly speculative, although probably not unrealistic.

Reduction of the gene pool

A species consists of its gene pool, and the individuals represent random manifestations of this. The size of the gene pool is an integral part of the identity of the species, and a diminished gene pool may represent a severe threat to the long-term survival of the species. Declining populations may therefore be dangerous, although little is known of the long-term impact of population sizes above a certain minimum. Very small populations - of a few hundred specimens or fewer - cause severe problems for the long-term survival of the species. Isolation of species in discrete populations of such limited size causes similar problems although they can be remedied. Such small insular populations are found especially among large mammals, such as lions and rhinos, which survive mainly in protected areas.

Similar problems occur in captivity, especially with captive breeding of animals which are rare or extinct in the wild. Only recently has a dialogue been opened between scientists and breeders, and breeding strategies have been formulated, although not implemented, for a few species or subspecies, such as the Siberian tiger. If such strategies are not followed, many of the species in captivity will become extinct. Much of the practice in captive breeding is adverse to long-term survival. Usually only a small part of the captive population actually breeds, and there will often be an active selection for certain characters, a selection which will needlessly diminish the gene pool. It can thus be argued that Przewalski's horse is already extinct and replaced by a domesticated horse of a similar appearance. It is one of the urgent issues in species conservation to ensure that captive breeding of rare species contributes to the conservation of that species.

Reintroduction

While reintroduction of a species in an area where it has been extirpated is legitimate, the current fashion of 'reinforcing' species with low population density is far more questionable. If the reason for the unnatural low population is not remedied one can hardly expect reinforcement to have any effect. But if the causes are remedied, most species will be able to increase their populations. In cases where the reinforcement is done with specimens from a population different from the original one, or even another subspecies, the result from a genetic point of view may be extinction of the original population/subspecies. Some of the peregrine falcon reintroduction in Scandinavia, for example, should be seen in this light.

Competition from Introduced Exotics

There is also a fashion to introduce non-indigenous species even in protected areas, without knowing the consequences. The justification is often to 'improve' the area, or to protect a species which may be threatened in its habitat. From Kenya alone there are several recent examples, e.g. Grévy's zebra in the Tsavo National Park and the roan antelope in the Shimba Hills. Neither of these species is indigenous to these areas, although they are to other parts of Kenya, and the potential ecological consequences for the closely related and possibly competing species (Burchell's zebra and sable antelope) are unknown. Fortunately the introduced species have not become established in either case, but it is alarming that such hazardous experiments are carried out, apparently with the blessing of the relevant authorities.

About twenty years ago a zoologist in Kenya introduced a salt-tolerant cichlid into Lake Nakuru. This may be why the lake has been transformed from a unique simple ecosystem to an ordinary bird lake. From a bird-watcher's point of view perhaps an improvement, but the world may have lost one of the simplest ecosystems known, and one of the greatest biological spectacles. The whole ecosystem of Lake Naivasha has also been profoundly altered by the introduction of a mammal, a fish and a plant from the Americas. One of the results is the extinction of an endemic freshwater fish. In this lake the introductions were caused by, or as by-products of, commercial exploitation and can therefore not be condemned as much as those done in the name of conservation.

Lack of planning

One sometimes wonders whether lack of planning and direction in the conservation world can be contributing to species extinction. Available resources are very limited in relation to the problem. There is a strong reluctance to apply the principle of triage (concentrating resources on projects most likely to succeed), to choose between competing demands, and to apply sufficient resources to do the job. In the meantime a kind of irrational triage is being applied where the size of the animal and the eloquence of its advocates seem the critical factors rather than the World Conservation Strategy criteria: genetic uniqueness and threat. Too many opportunities are lost because funds are diverted from one case to the next and resources are exhausted half-way through the work because other emergencies are coming up. An example: shall we a century hence be seen as having lost all species and subspecies of rhinos (undoubtedly an extinction-prone group) because we always used our resources on the hopeless cases? Or do we now have to decide which two or three forms to save? Will the conservation world assist the captive-breeding world in this choice? So far it has not been willing to do so, not even to discuss it. We seem to work according to two principles, which may not be the most productive for long-term conservation:

1. Refuse to accept that *any* species or subspecies may become extinct;
2. Always concentrate effort and attention on the terminal cases.

Should one at least be brave enough to discuss an alternative strategy?

The Species Concept

So far the Linnean species concept has been used in conservation. It is generally well suited, especially as conservation has predominantly focused on birds and mammals. But as conservation extends its attention to plants and to other animals, the species concept should be examined, especially in view of the above dictum that we should not allow any species or subspecies to become extinct.

It must be realized that in some animal groups and plants the Linnean species concept has little meaning, as in the following examples.

The freshwater fish *Aphyosemion bivittatum* is split up into a number of isolated populations in the watercourses along the coast of West Africa. The populations are morphologically identical, but differ in chromosome numbers and chromosome morphology so that they are reproductively isolated. In Central Africa the clawed toad *Xenopus* shows similar diversity in chromosome numbers in different waterholes. Zoologists have chosen not to make nomenclatorial distinctions between the fish populations, but they have described a large number of *Xenopus* species.

One species of African tree-frog *Hyperolius* is so variable that one could justifiably describe virtually every population over greater parts of its range as a distinct subspecies. Recent studies have also shown that the cichlid fishes of Lake Malawi and Lake Tanganyika can be regarded as species swarms with a very high number of species involved. Here are two examples of vertebrate groups where taxonomists from the Linnean tradition justifiably could describe hundreds, or even thousands, of species or subspecies, some of them with very small populations. In botany and among vertebrates, especially those with asexual reproduction, there are other complications.

Can we handle such groups the conventional way?

CONCEPTS OF THREAT TO THE SURVIVAL OF SPECIES USED IN RED DATA BOOKS AND SIMILAR COMPILATIONS

Paul Munton

CONCEPTS OF THREAT TO THE SURVIVAL OF SPECIES USED IN RED DATA BOOKS AND SIMILAR COMPILATIONS

Paul Munton

1. The Birth of Ideas of Rarity and Threat

As long ago as 1634 Thomas Johnson writing (in Latin) about his tour of England in search of plants, denoted rare species by giving their exact location in English and used a different type face for the commoner species, (Johnson 1634). Two hundred years later Colla and Bertero (1834) published a list of rare plants of Chile. Their concept of rarity meant essentially rare things having special value and described species found on what they described as a perilous journey. By 1891 lists of endangered species started to appear (Lucas 1891), and soon concern for endangered species was expressed in legislation in the London Convention on African Conservation of 1900. Lankester (1909) reviewed extinct and endangered animals, but his series of lectures is didactic in tone; he makes no attempt to list endangered species and much of the discussion refers to long extinct species such as dinosaurs.

The earliest species list discovered which can be regarded as an ancestor of the Red Data Books was William T. Hornaday's *Our Vanishing Wildlife* published in 1913, which, though evangelical in tone, includes detailed lists of species with notes on their status. He defined three categories of extermination:

The practical extermination of a species means the destruction of its members to an extent so thorough and widespread that the species disappears from view, and living specimens of it cannot be found by seeking for them.

The absolute extermination of a species means that not one individual of it remains alive. Judgement to this effect is based upon the lapse of time since the last living specimen was observed or killed. When five years have passed without a living "record" of a wild specimen, it is time to place a species in the class of the totally extinct.

Extermination in a wild state means that the only living representatives are in captivity or otherwise under protection.

In addition he gives a Roll Call of the Dead Species of American Birds; A partial list of North American Birds Threatened with Early Extermination; Species in Great Danger (birds); Large Mammals Completely Exterminated; and Species of Large Mammals Almost Extinct. These categories are not defined beyond the information contained in their titles. He also reviews the status of North American species state by state based on a three-question questionnaire sent to about 250 persons:

1. What species of birds have become totally extinct in your state?
2. What species of birds and mammals are threatened with early extinction?
3. What species of mammals have been exterminated throughout your state?

Based on the replies he listed Birds and Mammals that have been Totally Exterminated in Various States and Provinces; Birds and Mammals Threatened With Extinction. Some listed as threatened did become extinct but the majority still survive.

Twenty years later a Special Publication of the American Committee for International Wildlife Protection (ACIWP) listed African game species in need of protection (Anon 1933). There were no categories, but species were selected through "correspondence with scientists, game wardens and other interested persons concerning those species which appear the most in need of protection". There are few indications of the nature of the selection criteria, but Boardman (1981), in his review of *International Organisation and the Conservation of Nature*, remarks that species selection had more to do with trying to impress on local and colonial authorities the need for stricter enforcement of conservation legislation than with objective criteria of endangerment. Although uncategorized, this work was initially connected with the 1933 London Convention for the Protection of African Fauna and Flora.

In 1942 Allen produced a list of *Extinct and Vanishing Mammals of the Western Hemisphere*, also published by the ACIWP, with details of the species but without categorization. Those listed are described as being relevant to the Convention on Nature Protection and Wildlife Protection in the American Republics. Harper (1945) in a subsequent ACIWP publication entitled *Extinct and Vanishing Mammals of the Old World*, does not define categories of endangerment but does mention problems of defining which species should be listed. He included all African mammals accorded protection in Schedules A and B of the 1933 London Convention, even if subsequent research showed them to be commoner than previously believed, and remarked, "on the other hand the simple limitations of time and funds have excluded a certain number of rare and more or less endangered species whose status is probably more unsatisfactory than that of a good many included species." Harper also mentions two problems that recur throughout the history of RDBs and allied works: obtaining good data and the taxonomic difficulties of defining the nature of the group of animals under evaluation.

Both problems are still with us, especially the second with the present emphasis on gene conservation. It is worth noting that Harper is the first to set out information on species under a series of headings:

Former Range and Numbers;
Present Range and Numbers;
Date and Rate of Disappearance in each Country;
Causes of Depletion and Extinction, either Direct or Indirect;
Economic Uses or Importance;
Aesthetic Considerations;
Measures that have been or might be Taken for the Preservation of each Vanishing Species.

The number of lists of species needing protection rose after this time and several were presented at the Lake Success meeting of the International Union for the Preservation of Nature - the original name of IUCN (IUPN 1949). Notable lists are those of de Vos who listed ten vanishing mammal species, Coolidge who listed nine species derived from the Unesco symposium at Fontainebleau, France in 1948 and the 7th South Pacific Science Congress in New Zealand in 1949. Dharmakumarsinhji listed sixteen species of Indian mammals used as food by nomadic tribes and defined two categories of threat: Group A species were in a critical position, Group B were big game in need of careful preservation. A paper by Gams is notable for listing flora as well as fauna in Europe and being the first to use categories of threat since Hornaday's in 1913, of which he defined three in addition to a geographical dimension:

A. *Espèces déjà éteintes*
   i. Espèces complètement éteintes
      a) dans les temps préhistoriques
      b) dans les temps historiques
   ii. Espèces éteintes en Europe seulement
   iii. Espèces éteintes en Europe occidentale et centrale

B. *Espèces en voie de disparition ou gravement menacées*
   i. Espèces menacées dans leur aire entière
   ii. Espèces menacées dans leur aire européenne
   iii. Espèces menacées en Europe Centrale
   iv. Espèces alpines menacées

C. *Biocénoses en voie de disparition de l'Europe Centrale*

Nearly nine years elapsed before the next fully categorized list of threatened species when J.C. Greenaway's *Extinct and Vanishing Birds of the World* was published in 1958. Greenaway was aware of a number of problems, such as defining subspecies. He defined the following categories:

Extinct - known only from museum specimens and searched for

Probably Extinct - not certainly but probably extinct, from difficult areas of mountain forest

Known Only from Recent Osseous Remains

Hypothetical - known only from pictures or descriptions of travellers long ago.

Small populations - the fifth and longest list contains the names of small population that still exist but which because of special circumstances, usually intimately connected with interference by man, are thought to be in danger of extinction.

Some Rare Birds not in Immediate Danger

i. Forms that are rare in museum collections and about which nothing is known but the bare identity

ii. Some small populations that do not appear to be in immediate danger of extinction but because they are so few in numbers may be endangered should they be much disturbed in the future.

2. IUCN Red Data Books and US Legislation

Following the Lake Success meeting two main lines of development in threatened species are distinguishable. One line is associated with the development of Red Data Books by IUCN; the other is a large number of lists relating to, or influenced by legislation in the USA, especially the 1966 and 1973 Acts relating to endangered species.

2.1 IUCN Red Data Books

In 1954 IUPN produced a list of thirteen mammals threatened with extinction, selected from the Lake Success meeting, entitled *Les Fossiles de Demain* (The Fossils of Tomorrow). There were no sub-categories, It was not until 1964 that IUCN started to produce fuller lists. In that year it published a list of 300 rare birds (Anon 1964), fully categorized in terms of rarity and threat and including other denotations relating to introduced species or subspecies and the degree of protection afforded. The categories were:

Very rare and decreasing in numbers

Less rare but believed to be threatened

Very rare but believed to be stable or increasing

Status inadequately known - survey required or other data sought

Formerly rare but no longer in danger.

Additional symbols used were:

(a) full species

(b) subspecies

I introduced population believed more numerous than other indigenous stock

M under active management in a national park or other reserve

P legally protected, at least in some part of its range

R included because of its restricted range

S secrecy still desirable

The first IUCN Red Data Books appeared in 1966: Vol. 1 Mammalia and Vol. 2 Aves and, as stated in the preamble, included only the categories 'rare' and 'endangered'. A three-star designation indicated the most endangered species. Other categories may have been used but as the books were looseleaf and pages were replaced as they were revised it has not been possible to find a verifiable original 1966 sheet describing the categories used. (Joslin and Maryanka 1968 mention a three, two and one star listing suggesting a now abandoned comprehensive system of star listing). A large number of species were excluded which 'are rare in the sense that they are known only from a type specimen or type locality, unless there is good reason to believe that they are also endangered.' This excluded little-known species of which only the type specimen was known because they inhabit obscure or inaccessible places. A heading Species Status in the main text described what was known. In 1969 the categories used in the Red Data Books were revised to give a total of four, together with symbols very similar to those used by IUCN for birds above (Anon 1964). The categories were:

Category I Endangered: In immediate danger of extinction: continued survival unlikely without implementation of special protection measures.

Category II Rare: Not under imminent threat of extinction, but occurring in such small numbers and/or in such a restricted or specialised habitat that it could quickly disappear. Requires careful watching.

Category III Depleted: Although still occurring in numbers adequate for survival the species has been heavily depleted and continues to decline at a rate which gives cause for serious concern.

Category IV Indeterminate: Apparently in danger but insufficient data currently available on which to base a reliable assessment of status. Needs further study.

Green sheets were used to denote forms formerly endangered but which had recovered to the extent that their names could be withdrawn from the RDB. The symbols found in Anon (1964) were slightly revised with the substitution of E (Exotic) for the old I (Introduced) and with the introduction of T, indicating the species was subject to substantial trade.

In a continuation of the RDB series these criteria were revised by compilers Goodwin and Holloway in 1972 (Red Data Books Vol. 1 Mammalia 1972). All the extra symbols were dropped. The category Depleted was dropped, Vulnerable was introduced, more colour coding was used and the definitions under the headings were significantly revised giving a clearer relationship between the different categories. The categories and their definitions were:

Endangered (E) Red Sheets - Taxa in danger of extinction and whose survival is unlikely if the causal factors continue operating. Included are taxa whose numbers have been reduced to a critical level or whose habitats have been so drastically reduced that they are deemed to be in immediate danger of extinction. Also included are taxa that are possibly already extinct.

Vulnerable (V) Amber Sheets - Taxa believed likely to move into the endangered category in the near future if the causal factors continue operating. Included are taxa of which most or all the populations are decreasing because of overexploitation, extensive destruction of habitat or other environmental disturbance; taxa with populations that have been seriously depleted and whose ultimate security is not yet assured; and taxa with populations that are still abundant but are under threat from serious adverse factors throughout their range.

Rare (R) White Sheets - Taxa with small world populations that are not at present endangered or vulnerable, but at risk. These taxa are usually localized within restricted geographical areas or habitats, or are thinly scattered over a more extensive range.

Out of Danger (O) Green Sheets - Taxa formerly included in one of the above categories, but which are now considered relatively secure because effective conservation measures have been taken or the previous threat to their survival has been removed.

Indeterminate (I) Grey Sheets - Taxa that are suspected of belonging to one of the first three categories but for which insufficient information is currently available.

In the present series of IUCN Red Data Books there are some variations on the above. The Mammal, Invertebrate, and Amphibia-Reptilia Red Data Books have all introduced the CITES definition of extinction (Ex): Species not definitely located in the wild during the past 50 years. The IUCN Plant RDB (1980) uses 'extinct' where repeated searches have failed to find the species. Other additions have been:

Insufficiently Known (K) - Taxa that are suspected, but not definitely known, to belong to any of the above categories because of lack of information.

Commercially Threatened (CT) - Taxa not currently threatened with extinction, but most or all of whose populations are threatened as a sustainable commercial resource, or will become so unless their exploitation is regulated. The category applies only to taxa whose populations are assumed to be relatively large.

Threatened Community (TC) - A group of ecologically linked taxa occurring within a defined area, which are all under the same threat and require similar conservation measures.

Threatened Phenomenon (TP) - Aggregates of populations of organisms that together constitute a biological phenomenon, endangered as phenomena but not as taxa.

2.2 The Development of Lists of Endangered Species in the USA

At the same time that the IUCN Red Data Books were evolving, a series of Acts for species conservation were passed in the USA. These were accompanied by numerous lists of endangered species often with categorization systems that could be directly related to the Acts: the Endangered Species Protection Act 1966, the Endangered Species Conservation Act 1969, and the Endangered Species Act 1973. The US Committee for Rare and Endangered Species used the following definitions for a list of Threatened Fish and Wildlife (Anon 1966), the purpose of which was to focus attention on species and to stimulate corrective action:

Endangered - A species or subspecies whose prospects of survival and reproduction are in immediate jeopardy, due to one of many causes - loss of habitat or change in habitat, overexploitation, predation, competition, disease. Without help extinction will probably follow.

Rare - A species or subspecies not presently threatened with extinction but in such small numbers throughout its range that it may be endangered if its environment worsens. Close watch on its status is necessary.

Peripheral - A species or subspecies at the edge of its natural range in the US, which is rare or endangered within the United States although not in its range as a whole. Special attention is necessary to assure its retention in the US fauna.

Status Undetermined - A species or subspecies suggested as possibly endangered, but about which not enough is known to determine its status. More information is needed.

Under the 1973 Act (see also Annex I under US for full quotation) the category 'threatened' was introduced and definitions changed. 'Endangered' species are defined as 'any species which is in danger of extinction throughout all or a significant portion of its range', and a 'threatened' species as 'any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range'. This latter category is very similar to the 'vulnerable' category in the IUCN Red Data Books since 1972.

3. An Overview of Categories of Threat Found in the Literature

A total of 151 lists of threatened species, including Red Data Books and Red Lists, were reviewed together with their categories of threat and their definitions. Where these differ significantly from present IUCN or US Endangered Species Act (ESA) categories they are listed in Annex I. Categories vary considerably; some are complex involving several parameters but many are simple. A selection of 57 such categories is set out below, each one placed in one of several classes:

Species has Disappeared

Extinct	Probably extinct	Extirpated recently
Extirpated	Known only from osseous remains	
Species presumed extinct		Practical extermination
Absolute extermination		
Extermination in wild state		

Species is Under Threat

Threatened	Threatened phenomenon	Commercially threatened
Community endangered through trade		Almost extinct
Species is likely to become endangered		Very gravely threatened
Gravely threatened		Potentially threatened
Threatened with early extermination		Species in great danger
Threatened with extinction		

Road to Extinction

Species is Declining

Declining species	Endemic and slowly decreasing
Depleted	(Very rare and decreasing)

The Species is Only Found in Small Numbers

Rare	Very rare and decreasing	
Extremely rare		
Very rare but believed to be stable or increasing		
Less rare but decreasing		
Formerly rare but no longer in danger		
Some rare birds probably not in immediate danger		
Small populations	Less rare but believed to be threatened	
Unique	The rarest	Exceptionally rare
Sufficiently rare		

The Species is Only Found in a Small Area

Peripheral	Disjunct
Limit of range relict	Endemic
(Endemic and slowly decreasing)	Restricted local

There is Lack of Data on Species Status

Undetermined	Hypothetical
Insufficiently known	Status undetermined
Status inadequately known - survey required, data sought	

Miscellaneous

Care demanding	Additional species	Out of danger
Neither rare nor threatened		Migratory

Monitoring Needed

Situation à surveiller	Species needs monitoring

Categories in brackets occur in more than one class.

3.1 Extinction - The Key Category

The extinct category is the only status category whose definition is unequivocal: the species has disappeared. All other categories can be defined relative to it, and both the RDB categories and the USA legislation use 'extinct' as the reference point. Thus in the RDB's endangered species are those likely to become 'extinct', and 'vulnerable' species are those likely to become 'endangered'. Likewise in the ESA 1973 an 'endangered' species is one in danger of extinction, and a 'threatened' species one that is likely to become 'endangered'. The clearly definable nature of extinction allows a hierarchy of categories to be employed, each of which indicates the position of a species in relation to its final demise - the extinct state. This may be represented as follows:

Vulnerable ----------	Endangered -----------	Extinct (IUCN RDB)
Threatened ----------	Endangered -----------	Extinct (US ESA)

In this paper such systems are referred to as serial systems.

3.2 "Rare" and Similar Categories

The use of 'rare' is the most confusing of all the common categories; opinions on its significance often conflict. For example Benson (1977) states, 'Danger of extinction is usually associated with rarity, and to some extent a "rare" plant is, *per se*, a threatened one...even a slight change in the environment may eliminate the taxon, either by its direct effect or more often through favouring competitors'. On the other hand, in an *Inventory of "Rare" and "Endangered" Vascular Plants of California* (Anon 1980b) it is stated that '...not all "rare" species are "endangered" and not all "endangered" species are "rare".

Two classes of problems are associated with this category. The first is that although rare means that the species only exists in small numbers, it does not indicate whether the population is spread over a wide area and thinly dispersed, or distributed in small groups over a large area, whether it occurs in a very few aggregations where it is abundant, or in some intermediate form of dispersal. The distinction is important if the categories are used to decide what sort of protective action should be taken because action will depend on the distribution pattern.

The second problem is related. Should rarity be used as a parameter influencing category assignment rather than as a category on its own? The IUCN RDBs seem to use the category Rare to make it clear that although a species may only have a small population it is not necessarily either Endangered or Vulnerable but is nevertheless at risk. However, a population may be judged to be at risk only by considering the factors liable to affect it adversely. There is no clear relationship between small population size and risk except that a small population is at a greater potential risk than a similar but large population when similar adverse factors start to operate. Such similar cases are unusual, and the particular adaptations of some rare species to special sorts of habitat where they outcompete species that are abundant elsewhere suggests that rarity is often a specific adaptation rather than a lack of success and can be considered as a survival strategy in itself. Drury (1980) makes a similar argument and points out that only 20 per cent of species are very common.

As rarity does not by itself indicate the likelihood of extinction of a species, it would be more logical to use Rare as a parameter which influences decisions on the assignment of species to categories of threat, not as a category on its own, a strategy used by Beloussova (1981 - see Annex) who defines three classes of parameter each with different grades: degree of rarity, habitat deterioration, and species vigour. A species is then defined as Endangered if it is placed in some previously determined combination of grades in each category. A similar system is the REVD code used in California (Anon 1980b) set out in the Annex. This code defines four components R (Rarity), E (Endangerment) V (Vigour) and D (Disjunct) each with three classes. A species is evaluated for each component to give a systematic description of its status.

These problems have been inherently recognised by Leigh, Briggs and Hartley (1981) who distinguish between a Distribution Category and a Conservation Category, thereby making it clear that conservation category is independent of distribution. The Distribution Category (in Category 2) recognises species with a very restricted distribution which are 'vulnerable' to localised threats such as mining, building developments or hydro-electric schemes. Category 3 recognises species which may be as few in numbers as those in Category 2 but more widely distributed and liable to less localised threats, such as prolonged drought or overgrazing.

It might promote conceptual clarity to dispense with 'rare' and substitute a new category that would encompass its present use. Another alternative is that species now categorized as Rare in RDB's could be reclassified as Species of special interest, or Species in need of monitoring, so that any future change of species status could be quickly noted and acted upon, thereby dealing with the problem of rare species being potentially more at risk than abundant ones when adverse factors start to operate. This would allow a clear hierarchy of threatened categories: Extinct, Endangered, Threatened/Vulnerable, and In Need of Monitoring.

3.3 Categories Similar to Rare - Local, and Restricted

Cramp (1975), describing threatened birds of NE Europe uses a series of undefined categories including Local, Very local, Rare, Scarce. It is difficult to evaluate these because they are undefined, but the term local is interesting because it is normally used to mean rare in the sense of being restricted to a limited area. Given defined it in his list of *Rare and Endangered plants of New Zealand* (1981) as 'not particularly at risk but having a local distribution which suggests that in time the species could move into one of the above categories. These plants demand some sort of periodic monitoring'. In view of the problems discussed for Rare above, it is surprising that Local has not been used more frequently as a sub-class of Rare to describe species with small populations restricted to a small area.

3.4 Extinct and Extirpated

Concepts of area occupied by species are inherent in several categories. Local has been briefly discussed above as an area-defined version of Rare. Some of these concepts are administrative (Extirpated), others biological (Endemic and Relict) and others a mixture of the two (Limit of range, Disjunct).

Extirpated occurs frequently in species lists of states in the USA. It is a category that overcomes a widespread conservation problem: states, being parts of a larger whole, whether in Europe, the USA, the USSR or elsewhere, have to decide whether their conservation activities should be classified according to the greater unit or the lesser. The term 'extirpated' makes it clear that a species is no longer extant in the state or other administrative unit, but may be found outside it.

3.5 Peripheral, Disjunct, Limit of Range

Mohler et al (1974) in a review of the threatened species of Idaho, defines 'peripheral' species as those occurring at the edge of their natural range in that state but threatened with extermination within the US although not in their range as a whole - the example given is Richardson's blue grouse *Dendragapus obscurus richardsonii*. Ashton (1976) defines them as species or subspecies that reach the edge of their range in a state. Novakowski (1970), in a description of Canadian endangered mammals, does not list peripheral species because they are distributed on the periphery of Canadian territory, which may appear rare to Canadians but not, it is inferred, to others.

'Disjunct' is used by Wiegman (1979) in a description of rare and endangered vascular plants of Alabama. He defines these as - species that are significantly separated from the main area of distribution. Wiegman also uses the category 'limit of range' (Eastern Limit of Range, (ELR), SLR, ELR, WLR), defined as uncommon or rare species in Pennsylvania - because they are at or near the periphery of their distribution. Within the main body of their distribution these species may or may not be common.

3.6 Endemic, Relict

Wiegman (1979) defines 'endemic' as species confined to a specialized habitat and with limited ranges. He then describes a number of such specialized situations in Pennsylvania. Neither 'endemic' nor 'relict' are true categories of threat as they are not indicators of the likelihood of extinction. They may indicate that the species is confined to a limited area and is of special interest or value.

3.7 Migratory Species

'Migratory Species' is used as a category by Frugis and Schenk (1981) in a Red List of Italian birds. Again, this is not a category of threat, although it indicates general problems that may be associated with the conservation of a species and may be a factor in evaluating degree of threat.

3.8 Declining Species - A Key Parameter Discarded

Like 'rare' and its analogues, measures of decline are a key factor in deciding the extent to which a species is threatened. This idea was used in the earliest IUCN RDBs (1966), where it was inherent in the category 'Depleted' accorded to species which had a history of decline 'continuing at a rate which gave rise to serious concern'. Unlike Rare, it was soon dropped as a category. Categories involving concepts of decline relative to the total population size gives an excellent indication of the degree of threat to a species. The categories used by IUCN in 1964 (Anon 1964) - 'Very rare and decreasing'; 'Less rare but decreasing' and 'Very rare but believed to be stable or increasing' - would be valid status categories if they quantified rates of decline. However, to be able to say that a species is declining requires much sound data recorded over a long period; see for example Perring and Farrell (1983), who have obtained and used such data as described below. No information was obtained on why the concept 'Depleted' was abandoned by IUCN but it is possible that this was because data of suitable quality was often not available.

3.9 Categories of Uncertainty

In the sample eight different categories indicated that information was so limited as to prevent accurate categorization of the species. Here are some examples:

Indeterminate: Taxa known to be Endangered, Vulnerable or Rare but where the information is insufficient to say which is appropriate. (IUCN RDBs).

Insufficiently known: Taxa that are suspected but not definitely known to belong to any of these three categories. (IUCN RDBs).

Situacao desconhecida: Necessiadade de pequisas para informes concretos. (Anon 1972 - Brazil).

Undetermined Species: Information is so incomplete that status cannot be determined (Mohler 1974 - Idaho).

Status Undetermined: A species or subspecies suggested as possibly Endangered, but with insufficient information to determine its status. More information is needed (Anon 1966).

Status Inadequately Known: Survey required or data sought (Anon 1964).

Hypothetical: Known only by pictures and descriptions of travellers long ago (Greenaway 1958).

Unknown Status: Species probably belonging to one of the previous four categories but information insufficient (Frugis et al 1981).

These categories reflect one of the major limitations of the accuracy and usefulness of the categorization of 'endangered' species: its dependence on reliable up-to-date information covering their entire geographical range. Data are rarely perfect for the evaluation of species populations, and every categorization of a threatened species could usefully be covered by a qualification of doubt based on an assessment of the data's completeness. No attempt at this was found in the literature.

3.10 Miscellaneous Categories

In addition to those discussed so far, a number of categories express other aspects of species status.

Of special concern: Species that does not clearly fit into the 'Endangered', 'Threatened', or 'Rare' category, yet which, for certain reasons, warrants special attention (Pritchard vol 5 Plants - Florida US). This may include relatives of economically important species.

Care Demanding: Species (taxa) which do not belong to the categories 1-3 (ie Endangered, Vulnerable or Rare) but still require attention specific for each species. (Anon 1978b).

Intermediate (I): Taxa which are common now, but which may appear in the categories 'Vulnerable' or 'Rare' if their biotopes deteriorate further (Lelek 1980, *Threatened Freshwater Fishes of Europe*).

Situation à surveiller: No definition, (Géroudet 1969, *Birds of Europe*).

The function of these categories seems to be to allow listing of species long believed to be in need of action but which do not survive a rigorous process of categorization. They may also overcome feelings of unease about the unsatisfactory nature of categories or of the data available on the species involved.

4. Confusion in the Literature

4.1 Confusion of Cause of Threat with Species Status

Sometimes cause of threat is used in conjunction with a status category. For example, Carvalho (1968) has a category of species 'vulnerable to being threatened by exotic species recently introduced'. There is of course no reason why this should not be done if it indicates certain classes of action that would be appropriate, but it does raise the spectre of an immense number of categories which are hybrids of degree of threat and cause of threat. For example a list of threatened and endemic plants of the Council of Europe countries (Anon 1983) lists 23 causes of threat. Combined with the four categories of threat these would give some 92 hybrid categories - an unwieldy number.

4.2 Value Indicators Versus Status Indicators

Many categories used, such as 'Endemic', 'Relict' and 'Disjunct', have little to do with endangerment in the sense of indicating the likelihood of extinction. They do indicate that the species or population may be of special value, and provide information that would be of use in making decisions on priorities for conservation action. Relict species are of special interest as survivors of past periods and can be expected to have genotypes or phenotypes differing from those of more recently evolved species. It would be clearer and more useful if RDBs recognised that these are indicators of special value and listed them as such and not as categories of threat.

5. Relation between Evaluation of Threat and Action Needed

It is clear from the literature that lists of endangered species are composed, and the species within them categorized, so that decisions may be taken to protect those most in need. This can be done by evaluating the relation between the rate of decline and the population size. But the evaluation can be more complicated and take account of actions needed to arrest a species's decline, especially an evaluation of the extent to which action has been implemented, is practicable, and, if possible, the extent to which it will be successful. In an example below by Perring *et al* (1983) the degree of threat expressed through 'threat number' was partly evaluated by considering the extent to which the species was found in protected areas. It is quite logical to suppose that a species is under less threat if it is in effectively protected areas than if it is not. In RDBs and similar publications such considerations are normally included in the detailed text on the species.

Alternatively, it can be argued that the three key parameters are rate of decline, population size and the likelihood of the cause of threat continuing. This triple evaluation was not found as such in the literature.

Another treatment is that of Joslin and Maryanka (1968) who combine a description of the sort of actions needed with urgency of action. The purpose "is to make available a rapid reference to both the status and the nature of the action treatment required for each rare or endangered species". The result is a ten-category format describing aspects of status of the species and action needed.

Status has been classified in two ways:

a. by the IUCN star listing, which is graded on a scale of different levels of concern for each species as decided by the Survival Service Commission. (Category 9)
b. by a suggested revised listing, which is graded on a limited number of objective criteria, provided by the RDB. (Category 10).

The star listing ran from 1 = three stars to 4 = no stars. The revised listing was as follows:

1 = top priority species, defined as a species believed to be on the verge of extinction;
2 = top priority subspecies, defined as above but for subspecies;
3 = secondary species;
4 = secondary subspecies and tertiary subspecies.

To these categories are added eight action treatments defining the type of action needed. They are: human exploitation stopped; habitat destruction stopped; feral or introduced species removed; other; receives no legal protection; law enforcement is inadequate; not found in any reserve; not found in captivity.

The above are probably based on the symbols of the IUCN Red Data Book Vol. I Mammals (1966). Joslin and Maryanka (1968) list a large number of species indicating whether each of the ten categories are relevant to its problems. There seems to have been no repeat of this full attempt to describe species status and action.

6. Developments of the Categorization Concept

6.1 Progress in the Multi-Parameter Evaluation of Threat

The above review shows that development of concepts continues in a few of the many publications sampled, notably in the work of the Californian Native Plant society (Anon 1980) and Beloussova and Denissova (1981). Both arrive at an evaluation of threat by evaluating a species on a series of parameters. Leigh, Briggs and Hartley have both a distribution category and a conservation category. This sort of evaluation requires a lot of good quality information but will probably develop further as data of sufficient quality becomes available. Another example where good data has allowed concept development is the work of Perring and Farrell (1983) which reviewed the status of the Vascular Plants of the British Isles. This is remarkable for its coverage of data and treatment of concepts. The main development is a method of prioritisation among species using 'threat numbers' which attempts to be objective while admitting some subjectivity. These are made up of evaluations on five parameters.

i. Decline
- 0 = decline of less than 33 per cent
- 1 = decline of 33-66 per cent
- 2 = decline of over 66 per cent

ii. Number of Localities
- 0 = 16 or more locations (places in a 10 km square)
- 1 = 10-15 locations
- 2 = 6-9 locations
- 3 = 3-5 locations
- 4 = 1-2 locations

iii. Subjective estimate of attractiveness of the species and the likelihood of it being exposed to collecting pressure.
- 0 = not attractive
- 1 = moderately attractive
- 2 = highly attractive

iv. Conservation Index - an arbitrary figure related to the percentage of the localities of the species which are within nature reserves and other sites of conservation status.
- 0 = 66 per cent or more in protected areas
- 1 = 33-66 per cent in protected areas
- 2 = 33 per cent or less
- 3 = 33 per cent or less and localities subject to exceptional threat

v. Ease of access to public
- 0 = not easily reached
- 1 = moderately easily reached
- 2 = easily reached

Each species was evaluated for each parameter and the scores summed to give an overall threat number with a maximum possible of 15.

In addition, species were evaluated to give them categories compatible with the IUCN categories: Extinct, Endangered, Vulnerable and Rare.

The key categories - decline in numbers over time and decline in localities - are both evaluated, and these evaluations alone make this a powerful tool in evaluating relative species status. The conservation index is the development of an idea which appears in IUCN's evaluation of bird species in 1964, retained in the earliest IUCN Red Data Books (1966), where the existence of the species in a protected area is indicated by the symbol R. The idea was not developed further, possibly because the quality of data needed was not then available for most species. The remaining two categorizations reflect particularly British problems, of a country with a high population and highly developed agricultural industry leading to the concentration of people's leisure activities in relatively small areas of semi-natural habitat where rare species are likely to be found. In other countries these two categories may be regarded as less important. This sort of analysis can only be undertaken in a country with a large amount of skilled manpower relative to the area of potential habitat, and able and willing to collect the data needed. Such complex evaluation may not be possible in many countries at present.

It should be noted that the method of summing between unrelated categories as done by Perring and Farrell is statistically invalid, as the units used to score one category bear no clear or consistent relation with units used to score on another (rather like adding 10 francs and 50 centimes and saying they make a total of 60). Ranking scores within each category and then taking the median of the five categories may be a more valid treatment of this sort of data.

6.2 Species, Populations, Communities or Genes?

An area of potential confusion, and one which will change as ideas about resource conservation change, is concerned with the identity of the biological entity being accorded a status category. The unit in most common use is species and occasionally subspecies, but the conservation of genetic resources is now an important aim of conservation and infers conservation of genes rather than species or other taxa. Species are obviously a fairly well defined unit and convenient to deal with; on the other hand disjunct populations of the same species may have different phenotypes or genotypes which makes the population a useful unit. Listing threatened populations requires a large amount of good data on species biology, but it would allow much greater and more sensitive control of the biological resource being conserved.

Another alternative is to look at groups of species rather than populations. This is especially attractive where many species occupy similar habitats and where data on individual species biology is not great. The IUCN Invertebrate RDB uses the category of Threatened Community where ecologically linked taxa occurring in the same area are the basic unit. As a unit of categorization this also has the advantage of linking species conservation closely and systematically with protected area conservation. Threatened Community can be expected to be more commonly used as more information becomes available on the status of more species, and as enormous taxa like Insecta come within the scope of detailed compilations of endangered species.

Another related issue is the conservation of polyploid plants, which are of special interest because of their rich genetic endowment. Stutz (1979), in a paper on desert shrubs, raises the possibility that a small polypoid population with its rich and varied genetic constitution, has a much greater ability to adapt to environmental change than a large population of genetically uniform species. Genetic variability within a population may be an important measure of the vulnerability of a species to extinction, although the relation between genotype and survival is complicated and little researched from the point of view of conservation management. The elucidation of these relationships, so central to ideas of genetic resource conservation, needs more work, but the day can be foreseen when the data in a Red Data Book will include information on the genetic make-up of both animals and plants.

Perhaps one of the greatest conceptual changes in recent RDBs is the introduction of the Commercially Threatened category in the IUCN Invertebrate Red Data Book, (1983). This refers to commercially important species which, due to exploitation might be reduced to levels making them commercially unavailable but not necessarily to levels where they might be regarded as Vulnerable or Endangered. This is an anthropocentric category, reflecting the significance of the species to man and not only the species's status. Many more such categories can be expected to appear as a product of the present emphasis on genetic resource conservation. Threatened Economic Resource and Threatened Medicinal Resource are possibilities.

7. Parameters and Categories

7.1 Basic Measures of Threat

If it is to be useful a category of threat should give an accurate indication of the probability of a species becoming extinct or of how far it is from extinction. This requires a knowledge of the population size, the rate of its decline and the likelihood of the decline continuing. The first two are relatively simple, but the third involves judgments about the nature and persistence of the threat, requiring information on the species' total biology. Indeed a species may not be declining, but a knowledge of its biology shows it to be vulnerable to drastic loss of a resource. For example, an ungulate may be increasing in numbers, but such is its harmful effect on its vegetative resource that the population will shortly crash to a level where it can be considered endangered.

The consequent complexity of developing and using a categorization system has led to much muddled thinking in defining threatened categories. They have been confused with the threat itself; with the parameters that may be used to measure threat, such as rarity and distribution; with indicators of the value of a species as reflected in current thinking; and with lack of knowledge of a species. All these aspects of status have a place in a Red Data Book, but their real relationship to a degree of threat and to the status of living organisms needs to be more clearly set out. Such a restructuring of information should be in a form that encourages clear thinking and promotes the best decisions on conservation action, using the limited resources available to conservation bodies.

7.2 Summary of Parameters and Factors used to Evaluate Threat

Listed below are a series of parameters, factors or characteristics used to define status, the importance or value of the species and category of threat. These have been teased out of the literature reviewed where they were either confused with, or intimately connected with, category of threat.

A. *The identity of the biological entity* being conserved has been variously defined: species, subspecies, population, community, commercially viable population, phenomenon, biological spectacle. Ultimately gene could be used but was not in fact encountered.

B. *Parameters that may be used to arrive at Category of Threat:*

1. The population's rate of decline relative to its absolute population size over a period sufficient to differentiate decline from cyclical variation.
2. Identification of the cause of the decline (i.e. the nature of the threat) and an evaluation of the likelihood of this continuing or starting to operate.
3. An evaluation describing the rarity of the species and its type of distribution; for example:
   - Class A restricted to a small area
   - Class B small communities of species dispersed over a wide area
   - Class C single individuals dispersed over a wide area, or intermediate categories A/B and B/C
4. The rate of decline of the area occupied by the species relative to the absolute area at present occupied. (Rate of decline of other resources upon which the species is dependent e.g. vegetation, water or prey were not found as systematically used parameters in the literature sampled).
5. Degree of present protection, expressed as a percentage of species in a protected area, or other sorts of protection.

C. *A measure of adequacy or reliability of data* is inherent in categories such as Indeterminate or Insufficiently Known.

D. Species are increasingly seen as having a *value defined in terms of current thinking in the field of biological resource* conservation. The following value loaded terms, both anthropocentric and biological, were found:
   - Endemic
   - Relict
   - Disjunct
   - Special genetic richness - e.g. Polyploid
   - Commercially important species.

By extension of these, other terms not found in the literature may be suggested, such as, species of medicinal importance, of economic importance, or of importance to man, crop ancestors or ancestors of domestic stock.

Many of the above concepts are important in plotting the location of a species on the road to extinction. Others are important to those who have to decide which species should receive limited funds to secure their conservation. The meaning, significance and importance of each needs careful consideration if systems of categorization of threat are to be further refined.

8. The Refinement of Current Systems of Categorization

8.1 Doubt and its Evaluation

A knowledge of the doubt associated with a statement or hypothesis is a key to accurate judgment and is reflected in the use of statistical measures of confidence by scientists. The key to the efficacy of Red Data Books is the integrity of information contained within them. The original purpose of these compilations was to publicise the plight of species and provide information as a basis for action. Although the network of informants and the amount of data has greatly increased in recent years, few species are perfectly known. In some cases the use of one category to indicate a lack of knowledge (e.g. Indeterminate or Insufficiently Known) is an acknowledgment of significant lack of information. It would be useful if some indication were given of the compiler's degree of confidence in his decision to place a species in a certain category This is akin to a scientist indicating the confidence he has in the results of tests of his hypothesis.

8.2 The Potential of Serial Systems of Categorization

If categories of threat are to be useful to plan conservation action they should bear a clear serial relationship to each other and to the extinct category, as exemplified by the Threatened - Endangered - Extinct system used in the US, or the first part of the IUCN system, Vulnerable - Endangered - Extinct. The parameters and factors discussed above are often difficult to evaluate and the intuition of the experienced RDB compiler must, at present, be preferable to forcing data into inflexible categories to fit in with a preconceived formula. Nevertheless such considerations should not be allowed to prevent conceptual development.

Expansion of such serial systems leads to the problem that the further the category is from the objective category of extinction (or functional extinction) the less it has a clear meaning. It is possible to create a system which defines a potentially infinite number of serial categories each with a clear meaning, unambiguous relationships with each other, and practical implications. This is a simple system which shows how many years a species is from functional extinction or extinction, based on the types of information reviewed above. It is a serial system because each year a species moves up a category and the years to extinction are reduced by one if nothing is done to improve its prospects. Thus it might be described as, for example, 'a ten-year species' or 'a fifty-year species' depending upon its prospects. Such a system would give a direct evaluation of the time available for effective action, and be important in helping to set action priorities. Deciding priority species for action has been identified as one of the key functions of endangered species' compilations. Data is available for some species, and the lack for others could be compensated by development of appropriate statistical techniques to give fair estimates with some degree of confidence. Furthermore action proposals could include predictions of the shift in category expected to result from their implementation. Under such a system species conservation would become an exercise in scientific modeling with continual updating and testing of earlier hypotheses in the form of category estimates.

8.3 Why Only Species in Red Data Books?

The variation in the identity of the entities being conserved has already been set out at A above. It is worth commenting that if the present trend emphasising gene conservation continues future Red Data Books will deal with individual genes or sets of genes rather than species. Indeed a time can be foreseen when genetic engineering will allow huge numbers of valuable genes to be stored as part of a composite living organism, an animal with multiple features from many species or a vast polyploid plant bearing a hundred different flowers and fruits from its branches. The location and conservation status of genes within these macrospecies will be the function of RDBs of the future.

9. Conclusion

Although interest in rare species can be traced back to the 17th century, concepts of threat have evolved over a relatively short period. The main development has been since 1966, when the first Red Data Books were produced and when the USA's Endangered Species Protection Act seems to have stimulated the compilation of lists. Several stages are discernible. The process started with the development of an awareness of the survival problems of certain species - initially these were game species and others of economic importance. Subsequently, concerned and knowledgeable individuals came together to identify and agree lists of species which required action to protect them. This process required decisions on which species should be included in the lists on the basis of their need for protection. Subsequently a conscious effort was made to distinguish categories of degree of endangerment or need within the lists. Both conceptual development and more and better data appear to have been necessary to develop the categories of threat in common use today.

Although some lists of endangered species, especially in the USA, indicate that conservation action decisions have been taken, they, and especially their categories of threat, provide important information for decision making and planning in the conservation and sustainable use of biological resources. So it is necessary that their categorization systems are clear, and that the categories within each system bear a clear relation to each other. The system at present bears marks of evolution especially in the diversity of categories used and in the confusion between category and parameter often encountered. The category Rare is the most problematic; it is widely used, yet rarity may be a strategy for survival, not an indication that a species is threatened. It would be useful if there were clear indications of amounts of data available on species, perhaps by an indication of the degree of confidence the compiler has in her or his decision on each allocation of a species to a category of threat.

Future changes in categorization systems can be expected to reflect developments in thinking about biological resource conservation. Red Data Books may move away from species to deal with a number of new biological classes in which there is, or can be expected to be, increasing interest; for example, communities of species, populations, species of economic importance or genes. The development of serial systems is especially useful, and the potential power and usefulness of such systems may be easily understood by considering a theoretical system based on the number of years a species is from extinction. Such a system would be unambiguous enough to force compilers to think about and indicate the confidence in their assessment of the decision on each species and to review constantly both their techniques and decisions as they are tested by time.

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Note I

In accordance with Anglo-American Cataloguing Rules (Gorman M. and Winkler P.W. 1978 2nd Edition) all Red Data Books are listed under Red Data Books, not under the name of the compiler.

Note II

Notes on categories of threat found in publications follow in brackets (). (NC) means the publication contains no categories of threat. (IUCN) means that the categories are not significantly different from those used in IUCN Red Data Books after 1972. (ESPA) and (ESA) indicate the definitions are similar to those used in the US ESPA in 1966 and the ESA 1973 respectively. Other categories are self-explanatory. Where there are no notes the categories are in most cases listed in the text or in Annex I, where they are in alphabetical order.

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ANNEX I

A SELECTION OF CATEGORIES OF THREAT AND THEIR DEFINITIONS

This selection of categories from the literature is given in alphabetical order. Not all publications are included; others may be found in the main text, and those resembling the IUCN Red Data Book categories since 1973 are indicated (IUCN); definitions similar to the ESPA 1966 or ESA 1973 are indicated (ESPA) and (ESA) respectively.

Anon (1982) *Especias de Fauna Brasileira.* (Animals of Brazil). Mammalia. (Translation in brackets).

1. *Muito rara,* acreditando-se estar com populoacoes em declino acentuado. (1. Very rare, evidence that populations are declining strongly.)
2. *Menos rara, mas supondon-se ameacada.* Necessita atenta observacao. (2. Less rare, but believed to be threatened. Monitoring needed.)
3. *Muito rara, porem com populacoes estaveis ou em ascensao.* (3. Very rare, but population stable or rising.)
4. *Situacao desconhecida.* Necessidade de pesquisas para informes concretos. (4. Situation unclear. Need for more definite information).

(A series of complementary categories similar to those used by SSC using a number of asterisks to designate degree of threat is also used: 3 asterisks denotes a continuing strong decline leading to a situation of very grave concern; 2 asterisks signifies a situation giving rise to reasonable concern and 1 asterisk indicates a situation of less concern.)

Aves. Especie rare e aquela que dispoe de numero reduzida de exemplares os quais poderao estar concentrados suma pequena area ou esparsamente distribuidos em extensa regiao.

(Rare species with declining numbers often concentrated in small areas or sparsely distributed over a large area.)

Especie amencada de extincao e aquela que esta em processo de diminicao, atingindo um nevel que poe em perigo sua sobrevivencia. Um dos principais perigos e que o habitat de tal especie estega em parte ou totalmente em processo de modificacao brusca ou destruicao completa - a ponto de nao ser mais possivel manter populacao suficientemente numerosa para garentir a sobravivencia da especie. Muitas vezes os animais nao sa capazes de se adoptar a um ambiente modificado.

(Species threatened with extinction and in a process of decline to a level where survival is imperilled. One of the principal threats is the sudden modification or complete destruction of habitat to the point at which the population is too small to guarantee survival of the species. Frequently the animals are unable to adapt to a modified habitat.)

Anon (1977) *Endangered Wildlife of California*

Endangered animals are those 'likely to become extinct if something is not done'. Five questions were asked to decide if a species was endangered:

1. Does the mortality rate consistently exceed the birth rate?
2. Is the species unable to adapt to environmental change?
3. Is the habitat threatened by destruction or serious disturbance?
4. Does environmental pollution threaten its survival?
5. Is its survival threatened by the unwanted introduction of other species through predation, competition or disease?

Anon (1978-9) *Nordic Red Data Book*

Categories based 'in principle' on IUCN's Red Data Book but somewhat modified owing to the fact that the populations in question are found only within limited geographical areas and do not represent world populations. The categories below are from the English summary:

O. *Extinct*. Species (taxa) extinct or considered extinct as regenerating populations. Only those species which have disappeared since 1850 have been dealt with.

1. *Endangered*. Species (taxa) which are imminently endangered as regenerating populations unless action is taken.

2. *Vulnerable*. Species (taxa) for which the survival is not secured in the long range perspective. Includes a species severely declining in numbers or with diminishing geographical propagation and which may soon be moved to the endangered species category.

3. *Rare*. Species (taxa) which are not immediately endangered or vulnerable but are still threatened because their total population is smaller or they are very much restricted to a local area or (sic) disseminating.

4. *Care Demanding*. Species (taxa) which do not belong to the categories 1-3 but still require attention specific for each species.

Anon (1980), *Endangered and Threatened Species of New Jersey.*

Endangered: An endangered species is one whose prospects for survival within the State are in immediate danger due to one or many factors - a loss of or a change in habitat, overexploitation, predation, competition, disease. An endangered species requires immediate assistance or extinction will probably follow.

Threatened: A threatened species is one that becomes endangered if the conditions surrounding the species begin to, or continue to deteriorate.

Anon (1980) *Inventory of Rare and Endangered Vascular Plants of California.*

The authors point out that not all rare species are endangered and not all endangered species are rare. Found that to categorize in terms of degree of threat was too limited so they developed a four-component system that could be scored independently.

R (Rarity)
1. Rare but found in sufficient numbers and distributed widely enough for the potential for extirpation to be low at this time.
2. Occurrence confined to several populations or to one extended population.
3. Occurrence limited to one or a few highly restricted populations, or present in such small numbers that it is seldom reported.

E (Endangerment)
1. Not endangered
2. Endangered in a portion of its range
3. Endangered throughout its range

V (Vigor)
2. Increasing or stable in number
2. Declining in Number
3. Approaching extinction or extirpation

D (Disjunct)
1. More or less widespread outside California
2. Rare outside California
3. Endemic to California

A REVD code of 3,3,3,3, indicates the species is highly endangered.

Ashton (1976) *Amphibians and reptiles*

A. *Endangered*: A species or sub-species that has become reduced in numbers throughout its range (or has had its habitat reduced) to such a point that reproductive populations are extremely small or vulnerable to extirpation. Without full protection throughout its range, the species could be extirpated within the next 10-25 years. Also, a species is considered endangered within a state's boundaries if it is vulnerable to extirpation due to present trends in land or watershed use within the state.

B. *Threatened*: A species or subspecies that is represented in only a limited part of what was once its total range, with reduced populations due to habitat destruction or poor state or federal management. Those species or subspecies that have been cited as "threatened" in states encompassing 75% of their range are denoted by "*" in this report.

C. *Peripheral*: Those species or subspecies that reach the edge of their range in a state.

D. *Rare*: Those species that are considered rare throughout the state or are found in environmental conditions disjunct from the normal geographic range of the species.

E. *Extirpated*: Those species or subspecies that have become extinct in a state or for which there have been no verified specimens observed or collected for 25 years.

Ayensu, E.S. and De Philipps, R.A. (1978) *Endangered and Threatened Plants of the United States.*

(The following criteria are interesting because they differ from the ESA 1973 criteria on the grounds that those criteria apply to animals)

Endangered Species: Those species of plants in danger of extinction throughout all or a significant part of their range. Existence may be endangered because of the destruction, drastic modification, or severe curtailment of their habitat, or because of overexploitation, disease or even unknown reasons. Plant taxa that occur in very limited areas, such as those known from the type locality only, or those which grow in restricted fragile habitats, usually are considered endangered.

Threatened Species: Those species of plants that are likely to become endangered within the foreseeable future throughout all or a significant part of their range.

Recently Extinct or Possibly Extinct Species: Those species of plants no longer known to exist after repeated search of the type locality and other known or likely habitats. A number of species are extinct in the wild but preserved in cultivation.

A *rare species* of plant is described as one that has a small population in its range. It may be found in a restricted geographic region or it may occur sparsely over a wide area.

Beloussova L and Denissova, L. (1981). The definitions used to classify species in the *USSR Plant Red Data Book* are described. These are as follows:

1.1. A narrow endemic which occurs in small quantity is restricted to very specific habitats. According to quantitative characters it is possible to identify several groups:
   a) 'Unique' - the only plant or the only population with rare individuals up to 3.
   b) 'the rarest' one or a few populations with rare individuals totalling up to 20.
   c) 'Exceptionally rare' - several populations with dozens of individuals in each of them totalling up to 100 individuals.

d) 'Very rare' up to ten populations with a total number of individuals no more than 1000.

1.2. A species with a sufficiently wide range within which it occurs rarely or sporadically.

a) 'sufficiently rare' - dozens of populations dispersed unevenly, containing the same number of individuals, totalling up to 20,000 individuals.

b) 'rare' up to 100 populations distributed evenly with the tota number no more than 100,000 individuals.

2. Habitat Conditions

2.1. The conditions have deteriorated in part of the range.

2.2. The conditions have deteriorated within the entire range.

3. Vitality of a Species

3.1. 'a prosperous species' - normal development and renewal.

3.2. 'an oppressed species' poor renewal, in some cases incomplete cycles of development.

3.3. 'A vanishing species' - renewal is absent.

A species is identified as Endangered if it falls into groups 1.1. (a) or (b) 2.2., and 3.2 or 3.3.

Blab, J. et al. (1976) (Translation)

1. In the Federal German Republic, species which have died out or which have not been recorded and those that will soon be endangered.

1.1 *Disappeared and no recent records. Exterminated*: which if they reappeared would be protected. Those which were alive up to 100 years ago in the FGR, but which have almost certainly disappeared in Germany and worldwide.

Current Status:

- Animals which are certain to have died out or been exterminated.
- Unknown kinds whose existence was proved, but which after, say, 10 years cannot be found, and after careful search are declared extinct.

1.2 *Treatened Species*. These are animals in need of urgent measures. Their survival in the FGR is unlikely if the threats continue, or if special protection and help is not given by man.

Current Status:

- Species where one or very few isolated individuals or a very small population survives.
- Species which have declined in numbers over a long period and which are threatened in the greater part of their range.

2. *Highly Endangered*. Endangered in almost its entire native range.

Current Status:

- Species with low (breeding) success.
- Species whose native habitat has shrunk or locally disappeared.

3. *Endangered*. Becoming endangered in a large part of its natural habitat and distribution.

Current Status:

- Species with locally low or very low success.
- Species with populations in many places locally declining or locally extinct.
- Species limited by restricted resources such as limited forage plants.

4. *Potentially Endangered*. Species which exist in an area in a few scattered sites or where small populations live on the edge of their range but are not listed in 1 to 3 above. Even where no actual danger exists today these animals should be listed because of their restricted habitat. (e.g. because they would be vulnerable to road or mountain railway construction.)

Borodin, A.M. *et.al.* (1978) *The USSR Red Data Book*

Borodin uses two classes of threat:

Endangered, defined as being under threat of disappearance - numbers sharply decreasing; survival not possible without active support of man; reserves must be created for these species.

The second category is *Rare* - defined as having a natural tendency to decrease and disappear; to conserve them they must be protected. Special action programmes are proposed. This category includes narrow endemics and fauna and flora about which knowledge is lacking and further investigation is needed so that they may be categorized.

Species are also included in the RDB as a result of CITES listing to encourage research. Article 18 of the USSR constitution emphasises the need to preserve and study sustainable and rational use of resources.

The work includes suggestions for action by state governments, government bodies and scientists. Final decisions in the text have been agreed by the Ministry of Agriculture and ministers of the 60 Republics.

Bruder B. and Thonon, W.L. (1977) *Liste Rouge des espèces d'oiseaux menacées et rares en Suisse*. (No change in the revised list Bruder and Luder 1982).

Criteria are designated by symbols and numbers:

1. Espèces amenées par leur régression à un niveau critique des effectifs.
2. Espèces affectées d'une régression forte et continue depuis le milieu du siècle et qui ont déjà disparu de nombreuses régions.
3. Espèces dont la population n'a pas sensiblement diminué mais dont les effectifs sont faibles, donc en danger latent (moins de 300 couples ou colonies peu nombreuses).
4. Espèces chez lesquelles une régression s'est manifestée dans de vastes secteurs de la Suisse depuis le milieu, sans qu'il soit possible de définir dans quelle mesure.
5. Espèces qui n'ont sans doute jamais niché en grand nombre en Suisse mais qui sont un enrichissement de notre faune (moins de 50 couples en général).

Carvalho J.C.M. (1968) *Lista das especies de animales e plantas ameacadas de extincao no Brasil.*

Criteria (translated) are: Species threatened with extinction for whatever reason, even though not necessarily rare, can be included in the following:

a. Examples of decline where for whatever reason, the population has dropped to a level where it is placed in peril.
b. Species vulnerable to being threatened by exotic species recently introduced, predatory or competitive, especially species with a low reproductive potential or specialised diet.
c. Those whose habitat is totally or partially in the process of being destroyed or rapidly modified, to the point where it is not possible to guarantee survival of the species.

Chambers K.L *The Northwest United States*. Mentions identification by professional botanists of taxa within each state whose status was defined as "*rare*", "*unusual*" or of "*special interest*" including disjunct populations and populations which are marginal to the range of the species.

Coddington J., and Field, K.G. (1978) *Rare and Endangered Vascular Plants of Massachusetts.*

DCLN	Declining numbers in recent years
VULN	Vulnerable to depletion from collection and/or habitat destruction.
ENM	Endemic to Massachusetts.
ENNE	Endemic to New England.
RSTR	Restricted Range. Total range equal or less than size of New England - not necessarily endemic to New England.
DSJCT	Disjunct distribution in New England - population reproductively isolated or separated by at least fifty miles.
SNES	Single New England Station.
SMAS	Single Massachusetts Station
LC RE	Both rare and local
RARE	Usually occurring in one or few individuals per station.
LCAL	Local, usually occurring in few places in states, though populations may be large.
FEW	Five or fewer vouchsafed stations in state.
SLR WLR, NLR and ELR.	A population of the Southern, Western, Northern or Eastern limit of its range.

Cooper et al (1977) *Endangered and Threatened Plants of North Carolina*

A. Endangered

1. Within the confines of the state (of North Carolina). This includes peripheral forms which may be quite common elsewhere but whose continued existence as part of the North Carolina biota is clearly immediately at hazard; in danger of extirpation.
2. Nationwide i.e. included in, or being considered for the US list of endangered Fauna and Threatened Plant Species of the US, under the Endangered Species Act 1973. (Public Law 93-205); in danger of extinction (perhaps on a worldwide basis.)

B. Threatened

1. Within North Carolina; forms of which are likely to become Endangered within the foreseeable future if certain conditions are not met; forms which exhibit a considerable decrease in numbers deemed beyond the limits of normal fluctuation, or documented range contraction, but not yet considered Endangered.
2. Nationwide; under the provision of Public Law 93-205.

C. Special Concern

1. Because they exist in small populations (are rare) over a relatively broad range;
2. Because they are targeted for exploitation which could become extensive enough to pose a threat.
3. Because certain characteristics or requirements make them especially vulnerable to specific pressures; or
4. for other reasons identifiable by experienced researchers.

D. Undetermined

1. Because of insufficient data for precise assessment (suggestions for research aimed at generating these data are pertinent).

E. Recently Extinct or Extirpated

1. As indicated by historical documents and/or knowledge of committee members (each committee should decide its own definition of Recently.

de Beaufort, Françoise. *Livre Rouge des Espèces Menacées en France, Vol I Vertèbres.*

Six catégories:

1. *Disparus.*
2. *Situation critique*: Espèces amenées par leur régression à un niveau critique des effectifs.
3. *Régression forte*: Espèces affectées d'une régression forte et continuée et qui ont déjà disparu de nombreuses régions.

4. *Effectifs faibles*: Espèces dont la population n'a pas sensiblement diminué, mais dont les effectifs sont faibles, donc en danger latent.
5. *Régressions diverses*: Espèces dont une régression s'est manifestée sans qu'il soit possible de définir dans quelle mesure.
6. *Endémiques.*

de Viedma M.G. and Bustillo, M.R.G. (1976). *Libro Rojo de los Lepidopeteros Ibericos.* (Red Book of Iberian Lepidoptera).

En peligro de extincion (P) (HOJAS ROJAS). Taxones en peligro de extincion y cuya supervivencia en el area objecto de este studio es poco probable si los factores causales siguen operndo. Se incluyen taxones cuya poblacion se ha reducido a un nivel critico o cuyos habitantes se han reducido tan drasticamente que se supone estran pronto en peligro de extincion inmediata. Se incluyen taxones ya posiblemente desaparecidos.
Vulnerables (V) (HOJAS AMBRA). Taxones de los que se opina que entraran en la categoria anterior en un futuro proximo si los factores causales continuan actuando. Se incluyen aquellos taxones en que su mayoria o toda sus poblaciones estan decreciendo debido a reducido notablemente y cuya subsistencia no esta asegurada, y taxones con poblaciones aun abundantes, pero que estan bajo la amenaza de factores adversos serios en toda su area de distribucion.
Raros (R) (HOJAS BLANCAS). Taxones con poblaciones pequensas en el area objeto de este estudio, que no estan en peligro de extincion ni son vulnerables en el momento actual, pero pueden correr el riesgo de entrar en una de las dos categorias anteriores. Se trata generalmente de taxones muy localizados geograficamente o que viven en habitats de pequena extension, salpicados en un area mayor.
Endemismos (E) (HOJAS AMARILLAS). Taxones endemicosdel area estudiada que, aun cuando su status parezca seguro, pueden sufrir una rapida reduccion tanto por recoleccion excesiva como por cualquier otra razon perturbadora; o aquellos particularmente apreciados que sean buscados avidamente por colectores aficionados o comerciantes de insectos.
Migradores (M) (HOJAS AZULES). Taxones porcedentes de otras regiones geograficas que en forma anual o ciclica pasan por la peninsula Iberica, e incluso completan su ciclo biologico en la misma, pudiendo o no aclimatarse en este lugar de paso. Se incluyen aqui especies internacionalmente controladas por sus especiales condiciones de migracion a grandes distancias, que llegan a distintos paises del centro de Europa, a las islas Britanicas e incluso a zonas nordicas europeas.

du Mond (1973) *A guide for the selection or rare, unique and endangered plants.*

Endangered species are defined as those to which any of the following nine guidelines of rarity apply, and which are found in habitats that are about to be altered directly or indirectly by man's activity:

1. Found out of its expected context e.g. a short or long range disjunction.
2. Particularly subject to extinction or severe reduction in total population size by those of man's activities which have already caused a significant reduction in its numbers.
3. Found only in a very specific habitat of limited occurrence.
4. Thought to be a relict of a no longer extant vegetation association.
5. An indicator of a unique extant vegetation association.
6. Recognised as an example of a wide disjunction pattern.
7. Natural distribution limits are within the area in question.
8. Known to be introduced and established on a small scale.
9. Not consistently occurring as a member of any particular natural plant community, but more or less rare in the study area.

Field G.F. and Coddington, J. (1982)

Divides 224 species into four groups:

1. Species rare throughout their ranges.
2. Range limits - species at the northern and southern limits of their range.
3. Species with highly disjunct distributions.
4. Species with a restricted total range: endemic to Massachusetts, endemic to New England, or endemic to a small geographical area.

Frugis, S. and Schenk, H. (1981) *Red List of Italian Birds.*

Extinct Species. Species extinct in Italy after 1850 whose re-establishment would require special measures.

Status: - species whose extinction is scientifically documented.

Species in Danger of Extinction. Species which will become extinct if causal factors continue to operate.

Status:

- species the populations of which have reached a critical level.

Species rapidly declining but still present in very small isolated populations.

Species whose habitat has been so drastically reduced that extinction is near.

Vulnerable species. Species whose population is declining so that in a relatively short time they will enter the category 'in danger of extinction'.

Status:

- species whose populations are continually declining because of extensive habitat destruction and/or alteration of other environmental factors.
- species whose populations have been intensively persecuted and whose survival is not, as yet, assured.
- species with still abundant populations but which are potentially threatened by several factors operating in their Italian range.

Rare species. Species present in Italy with small populations which at present are not threatened nor considered vulnerable but whose "natural" rarity puts them in peril.

Status:

- species which in Italy are on the edge of their geographical range.
- species whose populations are very local within their range or which are present with very low density even on a wider range.
- species of recent (post 1950) establishment in Italy and whose populations need special conservation measures to facilitate their spreading into suitable habitats and their permanent establishment.

Species of unknown status. Species probably belonging to one of the previous four categories but for which at present there is not significant information.

Status:

- species whose distribution and/or abundance in Italy has not been the object of specific research.
- species which are at present doubtfully or irregularly breeding in Italy.

Migratory Species. Species for which Italy is of paramount importance during the migration and/or in a wintering area.

Géroudet P. (1969) *Les espèces d'oiseaux menacées en Europe.*

1. *Menace très grave.*
2. *Menace grave.*
3. *Menacée en voie de développement*
5. *Situation à surveiller.*

Categorisation is based on seven criteria:

1. L'étendue de l'aire de nidification et ses changements au cours des dernières décennies.
2. Les effectifs de l'espèce en Europe et la tendance génèrale de leur évolution.

3. La sensibilté écologique (en particulier la dépendance spécialisée à l'égard d'un biotope ou d'une nourriture).
4. La vitalité spécifique (surtout les taux de reproduction).
5. Les dangers directs (chasse, collection ou autre exploitation).
6. Les dangers indirects (modification du biotope, des ressources alimentaires, du climat).
7. La possibilité de réaliser une aide effective et d'améliorer la situation.

Given D.R. (1981). *Rare and Endangered Plants of New Zealand.*

Extinct (Ex). The species is believed to no longer occur naturally in the wild, although it may be growing in cultivation.

Endangered (E). In danger of becoming extinct. Survival in the wild is unlikely if factors causing endangerment continue to operate. In New Zealand we include those plants whose survival depends on continuous management such as weeding, dispersal of seed or manipulation of the habitat.

Vulnerable (V). Believed to be in danger of moving into the endangered category in the near future if the factors causing depletion continue to operate. Usually plants in this category are obviously diminishing in abundance or geograpical range.

Rare (R). Only small populations are known or the species is found only in restricted areas where it may be locally common. For the most part however the numbers of plants and localities where it is found are reasonably stable.

Local (L). Not particularly at risk but having a local distribution which suggests that in time, the species could move into one of the above categories. These are plants which demand some sort of periodic monitoring.

Insufficiently Known (K). Plant is only suspected of being threatened but more information is needed.

Hall A.V. et. al. (1980). *Threatened Plants of Southern Africa.*
Mainly IUCN categories but with category K changed to U and two additional categories:

U. Uncertain whether safe or not.

nt. Neither Rare Nor Threatened. Used for world status of plants believed to be neither rare nor threatened where they occur naturally elsewhere. The plants are listed in this report because their populations in southern Africa are significant in some respect, and are threatened or rare within the territory.

e/ne Endemic Non-Endemic. Used in a separate column to show whether a plant is or is not, confined to within the area in question in that list; endemic refers to southern Africa, in the second list to the country/province in question and in the third list to the degree square in question.

Hartley W. and Leigh, J. (1979) *Plants at Risk (Australia).*

This treatment replaces earlier categories for describing plants at risk (Probably Extinct; Endangered; Rare; Depleted; Known Only from Original Collection; Endemic) with a binary code, distinguishing the distribution of the species by a number and the conservation status by a letter. The codes are as follows:

RISK CODING FOR LISTED SPECIES:

Distribution Category.

1. *Species known only from the type collection or type locality.* Further study usually needed to ascertain present distribution and taxonomic status.

2. *Restricted endemic* whose populations are limited in range (eg. normally less than 100 km in maximum range.
3. *Rare species* occurring only in small populations, but over a wider area: often restricted to specific habitats (eg. sandstone areas, high mountain peaks).
4. *Species of geographic importance*, especially those with a disjunct distribution in Australia and overseas and listed only if the Australian populations are localised or sparse.
5. *Species* not fitting closely into the above categories, but considered to be *at risk*. This includes some once common species which, though still widely distributed, have suffered marked depletions in overall population size.

Conservation Status

X. *Species believed to be extinct.* Not collected in recent years.
E. *Endangered species* in serious risk of disappearing from the wild state within one or two decades if present land use and other causal factors continue to operate.
V. *Vulnerable.* Species not presently endangered but at risk over a longer period or if land use patterns are introduced which would be deleterious to the species.
n. *Other species* listed under 1-5 which are not currently endangered or vulnerable, and which are known to occur in National Parks and other declared reserves.

Heintzelman D.S. (1971) *Rare and Endangered Fish and Wildlife of New Jersey*

Endangered. An endangered species is one whose survival in New Jersey is in jeopardy. Its peril may result from loss of habitat, change of habitat, overexploitation by man, predating-adverse interspecific competition, disease, or because in New Jersey it is at the extreme edge of its range. An endangered species must receive help or extinction probably will follow.

Rare. A rare species is not presently threatened with extinction, but it occurs in such small numbers in New Jersey that it may become endangered if its environment deteriorates further or other limiting factors change. Careful watch of its situation is essential.

Undetermined. A species whose status is undetermined may be rare or endangered in New Jersey, but information currently available is inadequate to evaluate its status accurately. More information is needed since the species could now exist in dangerously low numbers in the Garden State.

Leigh J., Briggs J. and Hartley W. (1981) *Rare and Threatened Australian Plants.*

The system of classification uses two codes, a numerical Distribution Code 1,2,3 and an alphabetical Conservation Code X,E,V,R,K. They are defined as follows:

Distribution Categories.

1. *Species known only from type collection.* Further study may sometimes be desirable to confirm the taxonomic status of the species and field surveys are often needed to ascertain present distribution.

2. *Species with a very restricted distribution in Australia* and with a maximum geographic range of less than 100 km. This category also includes a few species which also occur outside Australia.

3. *Species with a range of over 100 km in Australia* but occurring only in small population which are mainly restricted to highly specific habitats. This category also includes a few species which also occur outside Australia.

Conservation Status:

X. Species presumed extinct. These have not been found in recent years despite thorough searching, or have not been collected for at least 50 years and were known from now well settled areas.

E. Endangered species in serious risk of disappearing from the wild state within one or two decades if present land use and other causal factors continue to operate. This includes species with populations possibly too small to ensure survival even if present in proclaimed reserves.

V. Vulnerable species not presently endangered but at risk over a longer period through continued depletion, or which largely occur on sites likely to experience changes in land use which would threaten the survival of species in the wild. (Used if there is an identifiable potential threat to the plant or if the population levels are particularly low - 100 plants or fewer for trees and shrubs).

R. Species which are rare in Australia but not currently considered endangered or vulnerable. Such species may be represented by a relatively large population in a very restricted area or by smaller populations spread over a wider range or some intermediate combination of distribution pattern.

K. (As for IUCN 1973).

C. Species known to be represented within a National Park or other proclaimed reserves. The species may or may not be adequately conserved within the reserve (S) as indicated by the conservation codes assigned to it.

* Species whose exploitation in the wild state is likely to affect their conservation status adversely.

\+ Species which have a distribution extending beyond the Australian continent.

Lelek A. (1980). *Threatened Freshwater Fishes of Europe.*

Uses modified IUCN criteria.

Endangered (E). Includes all species, including taxa supposedly extinct, with only a theoretical chance of being re-established or re-introduced within the former range of their distribution area. This category includes threatened species which occur in one or two small localities, where their abundance is also very low.

Vulnerable (V). Taxa which are rare, very sensitive to environmental changes caused by man. Such species are often common in unsuitable habitats, where their presence depends on artificial hatching, stocking and/or management.

Rare (R). This category includes taxa which were never abundant but were permanently present in suitable biotopes, and species which are rare today as their formerly large distribution area is now confined to a few remaining suitable biotopes.

Intermediate (I). Taxa which are common now, but which may appear in the categories V or R if there is any further deterioration in their biotopes.

Miller R.R. (1972). *Threatened Freshwater Fishes of the US*

Miller includes peripheral species in the rare category. He says such populations are often disjunct so isolated gene pools may have practical and scientific value.

Endangered. Actively threatened with extinction. Continual survival unlikely without the implementation of special protective measures.

Rare. Not under immediate threat of extinction, but occurring in such small numbers and/or in such a restriced or specialized habitat that it could quickly disappear.

Depleted. Although still occurring in numbers adequate for survival, the species has been heavily depleted and continues to decline at a rate substantially greater than can be sustained.

Indeterminate. Apparently threatened but insufficient data currently available on which to base a reliable assessment of status.

Mitchell, R.S. and Sheviak, C.J. (1981). *Rare Plants of New York State.*

Uses the ESA criteria but also defines *Extirpation*: "When a species is eliminated from a given area or ecosystem it is said to be extirpated there. Extirpation has the effect of eliminating special individuals whose peculiarities might be the key to survival of the species when conditions change."

Pritchard P.C.H. (1978-82). *Rare and Endangered Biota of Florida 7 vols.*

The same categories are used for all the vertebrate taxa but different categories are used in Vol. 5 for the flora. The categories used for vertebrates are as follows:

Endangered: Species in danger of extinction if the deleterious factors affecting the population continue to operate. These are forms whose numbers have already declined to such a critically low level or whose habitats have been so seriously reduced or degraded that without active assistance their survival in Florida is questionable.

Threatened: Species are likely to become endangered in the state within the foreseeable future if current trends continue. This category includes:

1. species in which most or all populations are decreasing because of overexploitation, habitat loss, or other factors.
2. species whose populations have already been heavily depleted by deleterious conditions and which, while not actually endangered, are nevertheless in a critical state.
3. species which may still be relatively abundant but are being subjected to serious adverse pressure throughout their range.

Rare: Species which, although not presently endangered or threatened as defined above, are potentially at risk because they are found only within a restricted geographic area or habitat in the State or are sparsely distributed over a more extensive range.

Species of Special Concern: Species that do not clearly fit into one of the foregoing categories yet warrant special attention. Included in this category are:

1. species which, although perhaps presently abundant and widespread in the state, are especially vulnerable to certain types of exploitation or environmental changes and have experienced long-term population declines.
2. species whose status in Florida has a potential impact on endangered or threatened populations of the same or other species outside the State.

Status Undetermined: Species suspected of falling into one of the above categories but for which available data are insufficient to provide an adequate basis for their assignment to a specific category.

Recently Extirpated: Species that have disappeared from Florida since 1600 but still exist elsewhere.

Recently Extinct: Species that have disappeared from the State since 1600.

Criteria for Plants.

Endangered. Species in imminent danger of extinction or extirpation and whose survival is unlikely if the causal factors presently at work continue operating. These species are those whose numbers have been reduced to such a critically low level or whose habitat has been so drastically reduced or degraded that immediate action is required to prevent their loss.

Threatened. Species believed likely to move into the endangered category in the near future if the causal factors continue operating. Included are species in which most or all populations are decreasing because of overexploitation, massive depletion of habitat or other environmental disturbance; species whose populations have been heavily depleted by adverse factors and the ultimate security of which is not yet assured: and species with populations which may still be abundant but are under threat from serious adverse factors throughout their range in the state.

Rare. Species with small populations in the state which, though not presently endangered or threatened as defined above, are potentially at risk. Included are species that may be localised within a restricted geographical region or habitat or thinly scattered over a more extensive range. They may be insular or otherwise isolated species or relicts with wide distribution. They may also be forms that are seldom recorded and which may be commoner than supposed, although there is reasonably good evidence that their numbers are low.

Species of Special Concern. A species that does not clearly fit into the endangered, threatened or rare category yet which, for certain reasons, warrants special attention.

Read R.H. (1976). *Endangered and Threatened Vascular Plants of Wisconsin.*

Endangered. Native plants with three or fewer stations known to exist in the state. Some with more than three are included where it is believed that a substantial number of the stations are destroyed or actively threatened.

Threatened. Rare native species which are known from more than three stations in the state, but are of very limited distribution in Wisconsin so as to cause concern of future endangerment.

Sidall J.L. et.al. (1979) *Threatened and Endangered Plants of Oregon.* Distribution is listed separately from conservation status, as follows:

Group 1. Range circumscribed; species endemic to a certain area.
- 1a. Very local endemic, presently known from only one site or a very small area.
- 1b. Regional endemic.

Group 2. Range wide; species rare, threatened and endangered throughout its range.
- 2a. Plants thinly scattered over a wide range, often occurring singly or in small groups; very rarely collected.
- 2b. Known for only a few widely disjunct populations.

Group 3. Species rare, threatened or endangered in Oregon, but more abundant elsewhere (or abundance elsewhere unknown); disjunct and peripheral in Oregon. (These species are of State concern and do not qualify for national listing).

Group 4.Unusual populations, such as primitive diploid populations in an otherwise polyploid species.

Rare: A rare species is one that is limited to a restricted geographical range or habitat, or one that occurs sparsely over a wider area. As the size of a plant's range increases the number of individuals and/or populations must decrease proportionally for the taxon to be considered rare. Therefore a listed species may be locally abundant but known from only one site; or it may occur as scattered individuals or in a very few populations over a wide range. Some species are naturally rare and not threatened; others once abundant have become rare as their populations declined.

Endangered: The ESA 1973 defines an endangered species as any species which is in danger of extinction throughout all or a significant portion of its range. For our purposes, all species known from only one population were considered to be endangered. Species known from very few populations, that are also highly sought after by collectors, or are being subjected to other active threats such as imminent loss of habitat, are also categorised as endangered. Species now possibly extinct are listed as endangered in this report.

Threatened: (ESA 1973 definition) The term has been applied to species whose populations are declining due to the destruction of either the plant or its habitat, and which will become endangered unless protected.

Species of special concern: (The Watch List) Species found to be too abundant to justify as rare, threatened or endangered, but which are declining and should therefore be monitored.

Disjunct: The term disjunct refers to populations which are widely separated from other populations of the species. A species that is known only from widely scattered sites can be said to have a disjunct population.

Peripheral: Peripheral populations are those at the edge of a relatively continuous range, such as a Californian species at the northern limit of its range in extreme south-west Oregon.

Siegfried W.R., et.al. (1976). *Rare and vulnerable birds of South Africa.*

This work uses the IUCN categories but in addition three sets of codes giving species status. These are as follows:

Distribution.
- A - Widespread in South Africa.
- B - Restricted in range to less than one third of South Africa.
- C - Localised to small areas.
- D - Peripheral.
- E - Endemic.

Abundance.
- A - Rare;
- B - not rare;
- C - Common;
- D - Not common.

Population Dynamics.
- A - stable and safe at present so far as is known;
- B - declining as far as is known;
- C - increasing as far as is known;
- D - not known.

Smit C.J. and van Wijngaaden, A. (1981). *Threatened Mammals of Europe.*

Uses IUCN criteria but selects species on a number of different criteria such as one from each European habitat and one threatened species from each country and one from each order of mammals, and from different categories of threat such as water pollution, overhunting, genetic "improvements" to game species.

Takhatajan A. (1975). *Red Data Book of Native Plant Species of the USSR.*

The categories are the same as that for Tanasiychuk listed below with the addition of an initial category 0, translated as follows:

0. Disappeared species; Not seen in nature for a period of years but may perhaps survive in separate inaccessible areas or are present in cultivation.

Tanasiychuk V.N. (1981). *Data for the "Red Book" of insects of the USSR.*

Lists four categories after Bannikov 1976, but rejects the fourth on the grounds that most species would fall into that category. He considers that the Red Book should contain the fairly conspicuous more or less fully studied insect species characteristic of specific endangered biocenoses, and the protection of such species should result in the protection of their biocenoses.

1. *Endangered species* under the threat of extinction, the rescue of which is no longer possible without the adoption of special conservation measures.

2. *Rare species*, not yet directly threatened with extinction, but occurring in small numbers or in such small areas they may rapidly disappear.

3. *Declining species*, the numbers of which continue to decline rapidly and steadily.

4. *Indeterminate species*, little known and evidently under threat of extinction, but the lack of information about them does not enable the condition of the population to be assessed reliably.

U.S. Endangered Species Act 1973.

Definitions

(4) The term "*endangered species*" means any species which is in danger of extinction throughout all or a significant part of its range other than a species of the class Insecta determined by the Secretary of State to constitute a pest whose protection under the provisions of this act would present an overwhelming and overriding risk to man.

(14) The term "*threatened species*" means any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

White D.J. and Johnson, K.L (1980). *The Rare and Vascular Plants of Manitoba.*

Rare: a rare plant is one that has a small population within the province or state. It may be restricted to a small geographical area or it may occur sparsely over a wider area.

A *threatened plant* is one that is likely to become endangered within the foreseeable future over all or a significant portion of its range in the province or state.

ON THE DEFINITION OF THREATS TO THE SURVIVAL OF SPECIES

William K. de la Mare
International Institute for Environment and Development, London.

Introduction

The aim of this discussion paper is to consider the factors involved in developing uniform and objective definitions to describe the degree of threat to survival faced by species or populations. The treatment is far from exhaustive; the aim is to elicit further ideas on the subject.

The first problem is: what is the aim of such definitions, and thus implicitly what are the aims of conservation? To define these as the prevention of biological extinction of species seems altogether too narrow. The aims must surely be more ecologically orientated: to conserve healthy, functioning communities of plants and animals. The reasons for doing so are diverse and range from the cultural and aesthetic through to commercial and subsistence exploitation.

The need for conservation, of course, arises from the conflict between many other human objectives and the maintenance of biological diversity. This conflict itself complicates the problem because the aims of conservation have to be balanced against other important human needs. This leads to rather different conservation goals for different species. For example, the conservation objectives for many large terrestrial mammals are, to a large extent, related to cultural and aesthetic considerations, coupled with economic objectives such as tourism. Thus, a suitable degree of conservation may often be achieved by appropriate reserves. On the other hand, many fish species are managed primarily as resources and are not usually considered to be candidates for biological extinction. However, this should not exclude them from being the object of conservation classification. It has been amply demonstrated that fish stocks can be reduced to very low levels by exploitation. Another problem is how to fit into a conservation framework those species that are pests or considered to be undesirable and whose eradication is a goal.

Thus, it is assumed in this paper that the role of the definitions is as a tool for monitoring the status of species for a scheme of conservation whose objectives include the prevention of 'functional' extinction. Functional extinction occurs when a species has been reduced to the point where it no longer plays a significant role in its habitat. Fortunately, functional extinction is not necessarily permanent, but it must not be assumed that it is an event without consequences both for the individual species and for an ecosystem as a whole.

The process of extinction is fundamentally one of demography. If the rate of mortality in a population exceeds the rate of reproduction it will decline, and if this continues long enough extinction will follow. It can be noted from this simple statement that the actual absolute abundance of a population may be irrelevant, except in so far as it may be a factor causing a decline in the rate of reproduction or an increase in the rate of mortality. Of course, very low levels of abundance are relevant, but the point is that high levels of abundance do not, by themselves, confer immunity to threat. It is easy to imagine situations in which a population with few individuals is less likely to decline to extinction than one which contains perhaps millions of individuals.

The concepts presented in this paper are applicable whether a species, a population or an entire community is the entity to be classified. The term species will be used in this general sense throughout.

Some Simple Definitions of Degree of Threat

Let us set up some simple definitions under which species may be classified by degree of threat to their continued survival. From these definitions we can discuss, in the sections that follow, the nature of threats within the framework provided by the definitions and, in particular, on what bases judgments on classification would have to be made. These definitions are not introduced as necessarily good definitions but as points around which to develop discussion at a later stage.

As already mentioned the role of such definitions must be seen in the context of the conservation objectives to be achieved for each species. However, the aim of such definitions must be precautionary and thus represent the degrees of danger short of probable extinction that a species or population may face. The definitions should also permit all species to be assigned to a category.

1. An *unendangered species* is an abundant species with a wide distribution, able to survive in a variety of habitats and 'known' to be at a level of abundance and distribution comparable with or exceeding those of historic times.

2. A *vulnerable species* is one which faces no known threat but, should a threat develop, would be likely to be classified as *endangered*.

3. A *threatened species* is one which is *likely* to decline in abundance for the foreseeable future, or which has been classified as *endangered* but is *known* to be increasing and has not reached a level of abundance comparable with historic levels.

4. An *endangered species* is one for which extinction is possible within the time span which would be required for conservation measures to take effect.

5. A species of *indeterminate status* is one which is not endangered, threatened or vulnerable but is not known to be unendangered.

These definitions also contain the criteria by which species may be reclassified in either direction. These definitions are not necessarily complete at this stage but are formulated so as to incorporate a number of important aspects, and it is appropriate at this stage to include some explanation of their function for each definition in turn.

1. The definition of unendangered looks relatively straightforward but it does have two problems, namely, establishing historic levels of abundance and distribution, and deciding if current levels are comparable. The word comparable is deliberately chosen for this definition in order that different levels of abundance relative to original levels can be set as appropriate. Thus for slow-breeding long-lived species whose abundance does not naturally fluctuate to any great extent, a comparable level would be a high proportion of the historic level. On the other hand, a species with a high turnover and normally subject to large fluctuations in abundance could still be considered unendangered at lower levels relative to historical average abundance. The definition is specifically worded to highlight the difference between 'unendangered' and 'vulnerable'.

2. The classification of vulnerable is designed to cover species or populations consisting of relatively few individuals or restricted to a small area. An example would be a species endemic to a small island. This classification could also be useful for a species of great commercial value where overexploitation would be likely in the absence of strict controls.

3. The definition of threatened species is in two parts. The first part is to deal with a species or population which is still abundant but is likely to be declining slowly. The classification is to indicate that conservation measures are needed but the time scale for them to have an effect is less than the time scale in which the species will decline to critically low levels. The second part of the definition covers the case where a suitable monitoring programme shows previously endangered species to be increasing. They are not covered by the first part of the definition since they are increasing, but they are in a

state where continued conservation measures are necessary if they are not to revert to the endangered classification.

4. An endangered species is one which requires urgent conservation action. It should be noted that in this definition the time-scale in which extinction is possible is the time-scale for conservation to have a measurable effect. Thus the time-scale has to include an 'institutional' component, that is the time taken by those responsible for the conservation of the species to agree on the necessity and means of achieving it, an 'action' component for the time taken to implement conservation measures and finally a monitoring component, which is the time required to establish whether the species is responding to the conservation measures. Thus the time-scales may be as short as a few years for dynamic species, but many years for those with low reproductive rates. In particular, monitoring times may be long if the effort is low or the methods insensitive.

It can be seen from the definition of 'threatened' and 'endangered' that the degree of threat is a function of the rate at which a species could decline relative to the length of time required to establish effective conservation. Thus the dynamics of the species is linked to the dynamics of conservation action. A species under one national jurisdiction may be classified as 'threatened' if this nation has responsive institutions for dealing with conservation matters and the resources to implement and monitor conservation measures; a species in similar circumstances but under the jurisdiction of a nation unwilling or unable to respond to the need for conservation could be classified as 'endangered'.

5. The indeterminate classification includes those species not felt to be facing any particular threats. They may be species which are considerably less abundant than they once were but are nevertheless thriving.

The Nature of Threats to the Survival of Species

In this section we will briefly review the nature of threats to the survival of species under a number of sub-headings, recalling that for the purposes of this paper the term species applies to populations and communities as well.

Abundance

It has long been recognised that the extinction of a species is an event that has a non-zero probability and that this probability increases as the abundance of the species is reduced. The aim of conservation is to prevent this probability from rising substantially above the natural level.

Being at low levels of abundance is in itself dangerous, since the species may be dramatically affected by random events, which at higher levels of abundance would be of little consequence. For similar reasons, the extirpation of a population of a species may significantly increase the risk to the species as a whole. The reduction of genetic diversity may hinder a species from responding to longer term environmental trends.

In general, reduced levels of abundance lead to improved demographic performance. However, it is widely held, at least for many species, that there may be critical levels of abundance below which extinction becomes inevitable. Unfortunately, the determination of where such critical levels lie is virtually impossible, and in any case extinction is a random event and there can be no hard and fast level above which lies safety and below which lies disaster, but rather a continually increasing probability of extinction as abundance is reduced. However, it should be possible to identify features in the life history of an organism which expose it to an increased risk of further decline as its abundance is reduced. For example, a species with a wide distribution which relies on chance encounters for reproduction declines when the overall density declines to a point where such encounters become rare.

Furthermore, there is no reason to suppose that in general, if an ecosystem is seriously perturbed by the reduction in abundance of a species with a major role in that system, that it will ever return to its initial state. However, being at high levels of abundance does not, of itself, prevent a species from being at risk. It is the trends in abundance which are important.

A much more serious problem in this context is that, for many species, absolute abundance is very difficult to determine, and worse, determination of trends in abundance are even more difficult. This presents a problem to which we will return later, namely, how to classify species when there is uncertainty in estimation of abundance and trend in abundance. Another pertinent consideration is what aspect of abundance is relevant to survival for the species under consideration. For many species this is obviously absolute numbers, but for many other species biomass or density may be more useful characterisations of abundance.

Under this sub-heading we can also consider the threats that may occur due to changes in abundance of one or more components of a population relative to the population as a whole. For example, exploitation may concentrate on one sex or one age class of population. Such exploitation may create imbalances in a population which expose it to risks of decline over and above that due to exploitation by overriding compensatory density dependence.

Habitat

Obviously the destruction of habitat is a threat of the most serious kind, since it may lead to an increase in mortality, decline in reproduction rate or both. Furthermore, this threat is likely to be at worst, irreversible, or at best, involve such a long time span in regeneration that even long-lived species would be endangered. Many species have particular requirements, critical for their survival, but these may be present in only a fraction of their total range. Another problem in this class is that the migratory habits of a species might be disrupted without any particular damage occurring in either breeding or feeding areas.

Habitat may be lost to a species from other causes. The introduction of predators, more efficient competitors, parasites or disease are all likely to reduce populations, and in some cases, conservation measures may be virtually impossible. Communities which are isolated in some way may well be classified as vulnerable because any such introduction would be a serious threat.

Habitat may also be so degraded that a species is put at risk. Two obvious examples are pollution and disturbance. For many species it may be more relevant to classify the habitats themselves under definitions similar to those given earlier.

Exploitation

Defining threats due to exploitation may be more problematic. Many species have proved rather resilient under exploitation. For others, the economics of harvesting have been such that exploitation has become unprofitable before they have been reduced to critical levels. However, many have been overexploited, and the development of some general criteria which characterise the likelihood of overexploitation should be relatively straightforward. In this way vulnerability can be established.

The problems arise in determining the threat that exploitation represents in a given instance. Here the factors to be considered in assessing threat are not only biological but also economic and administrative. Of particular relevance is the nature of controls on exploitation and the methods used to monitor the status of the exploited species. Many methods used to monitor the abundance of populations are subject to high degrees of variability, and this is often large enough to mask any trends in abundance until a species has been substantially reduced for a considerable period. Unfortunately, with many exploited species, even when the trends have become clear, conservation methods have been delayed for political or economic reasons.

The effects of exploitation may not be confined to the target species and thus other species may be put at risk and often the mechanism by which this would occur may not be obvious. Another problem is that selective exploitation of a population may distort the population structure itself in ways which will lead to further declines in abundance even if exploitation were to cease.

Uncertainty

The definitions given earlier are reasonable as far as they go, but the problem is one of judging the class to which a given species belongs. In the large majority of cases this judgment will have to be made from limited and uncertain information. For many species the data on the abundance is sparse. For others, that have been extensively exploited, there is a great deal of data but, in general, these have not allowed precise estimations of population abundance and trend.

In some cases there are measures of uncertainty, often expressed in terms of confidence limits around some estimated parameter such as population size or coefficient of natural mortality. However these usually under-represent the true uncertainty in the parameter estimate. Estimation procedures are usually derived from formal statistical theory (though this is not always so) and the results obtained, including confidence limits, are only correct if the measurements which form the basis of an estimate are affected by chance alone, i.e. that sampling has been random, and that many other assumptions also hold. The underlying assumptions are often untested or virtually impossible to test. The estimates of reliability usually apply to only one step of the estimation process. The uncertainties related to the quality of the data and any departure from underlying assumptions are not included, usually because it is not obvious or even known how to assign values to such sources of error.

A significant problem for the analyst attempting to classify a species is that it is difficult to decide the weight to give to published research. The quality of scientific research is very variable and the results depend upon the analytical skills and insight of the researchers. Unfortunately, many biological researchers do not have critical insight into methods of statistical numerical analysis. The problem for the analyst is to gauge such factors. This is usually impossible without recourse to further analysis of the raw data, and of course, the analysts themselves may not be particularly skilled in quantitative science. Thus we have another dimension of uncertainty, namely, the amount of faith that can be placed in the basic quantitative science relating to a given species.

The sources of threats can usually be enumerated, but it is a much less tractable problem to estimate the strength of their effect on a species. We may be aware that some feature of a habitat may have changed but be uncertain of the impact of this change. In the management of exploited species, that which cannot be measured is often assumed to have no effect. Given the lack of precision of many estimation procedures, such an approach entails risks and is obviously inappropriate for the purposes of the species classifications under discussion.

The answers to such problems can only be obtained by monitoring a species, but, given that there are limited resources for research, one of the valuable outcomes that should come from a system of classification is an indication of priorities. So it would be highly desirable for the method of classification to deal with uncertainty in some practical and numerical manner even in the cases where direct measurements are not available.

The Problem of Objective Classification

The problem is: how do we fit the diverse problems hinted at in the earlier discussion into only five classes? In particular, how can this be achieved as objectively and consistently as possible? Consistency in this context means getting the same classification from different analysts working from the same data.

By themselves, the definitions of classes of threat are insufficiently structured to allow objective classification. A five-point scale is too coarse to describe the degree of threat to species. However, such definitions are far from useless because they convey obvious meaning and encapsulate major relevant concepts. Of course, some supplementary definitions would be required to clarify the intent of the five classes.

To produce a completely objective system of classification is impossible but subjective systems become more consistent if they are structured. So one solution to the dilemma is to have a much finer scale of degrees of threat on which we make the five classes correspond to given ranges.

In concept, one could have a check-list system, in which given factors would be assigned scores for a species as it is analysed. Where the answers are unknown or uncertain, this too would result in a score. Careful design of the scoring system would give the scale desirable properties. For example, a species about which very little is known should achieve a score which assigns it to the 'indeterminate' class. However, such a case should only require the identification of some negative factors to cause it to be reclassified as 'threatened'.

Some scores, such as the likelihood of decline or the determination of whether extinction was possible within a given time frame, would have to be based on demographic parameters and determined from formulae or tables. Work is already under way on the development of such tables and formulae for fisheries to identify sustainable exploitation rates, and these incorporate an allowance for the random fluctuations which can occur in population size. The underlying methods used to compile these tables can be used instead to estimate probabilities of catastrophic population declines under given conditions. Where estimates of population parameters can be assessed for uncertainty, reasonable 'worst case' values can be assumed.

Such a scoring technique can also incorporate abiotic factors, such as the methods of management and monitoring used for an exploited species or the effectiveness of the institutional framework under which conservation measures would be implemented. For example, some methods of monitoring an exploited species give reliable results only after a significant change in population size has occurred. A classic instance is methods based on the analysis of catch per unit effort, where a population has to be substantially depleted before reliable estimates are obtained. A management system based on such indirect measures, which yield information late, should attract a worse score than one based on direct censusing techniques, if these are of sufficient precision.

One advantage of a structured scoring method is that it helps to identify priorities and also reveals areas where our knowledge is deficient. Such a system also has the logical structure which renders it ideal for a computer data-base. However, it must be concluded that the design of such a scoring system would be a considerable task, requiring contributions from specialists in a variety of areas. Even if a scheme of classification that would work in all cases were to prove elusive, the attempt to produce it would, in itself, generate new views on the nature of threats to the survival of species.

Examples of How Some Species Might Be Classified Under Such A System

In order to clarify how such a system would work, let us briefly consider the classifications of the following species, chosen because they represent some of the diverse problems surrounding an objective assessment of the threats they face (or faced). The species considered are blue whales *Balaenoptera musculus* in the Antarctic, the Atlantic puffin *Fratercula arctica* in the Lofoten islands, harp seals *Pagophilus groenlandicus* and hooded seals *Cystophora cristata* in the north-west Atlantic, and finally the North Sea herring *Clupea harengus*.

The Blue Whale in the Antarctic

First, a brief summary of the salient facts. The blue whale declined due to heavy exploitation over thirty years until it was reduced to only 1 or 2 per cent of its pristine abundance. The density is now so low that depensatory mechanisms in reproduction cannot be ruled out. Low levels of monitoring effort show no clear trends of increase and in any case the time-scale of recovery will be long, of the order of a hundred years or more. The habitat has been disturbed by commercial whaling, but there is no particular reason to suppose the effects are irreversible. However, if a large scale krill fishery develops, this could well have adverse effects on the recovery of the populations.

If the definitions and scale of classifying threat had been in operation after World War 2, the blue whale would have had to be assigned to the 'threatened' category. If the system was to have any hope of success, by the early 1950s, blue whales in the Antarctic would have had to be classed as 'endangered'.

One reason for citing this example is that it suggests we could analyse the history of a number of species, where reasonable amounts of data exist, to 'calibrate' our scale. The other reason is to indicate that such a scale should still classify the blue whale as endangered even though for more than fifteen years it has been reasonably effectively protected from exploitation. This raises an interesting issue: when some conservation measure expected to reduce the threat to a species is implemented, how should the classification system respond? It would seem reasonable that the score should improve, obviously not to the point where the species would be reclassified immediately, but perhaps sufficiently to alter its position in a scale of priorities. However, this would involve a judgment of whether the conservation measure is likely to be effective.

A related issue is: in the absence of any new threats should a classification decay after conservation measures have been effected? If, in fifty years time, blue whales are still seen in the Antarctic, should their score on our scale reduce automatically, in the absence of any definitive monitoring of trends? In principle, this sounds reasonable. However, the relevant time-scale depends on the dynamics of the species. For example, one might expect to see some blue whales in fifty years time, even if their reproductive rate had fallen to zero. If, on the other hand, blue whales were still seen after 200 years (several blue whale lifetimes) then it does not seem unreasonable that their score should improve. This example seems far fetched because these times are so long. The issue would be more acute for a species with a faster turnover. Given that we have considered ignorance to be a threat in itself, such a property, though reasonable, does not sound appropriate. In the absence of knowledge that a population is increasing, it should retain its classification.

Puffins in the Lofoten Islands

For our second example we take the population of Atlantic puffins in the Lofoten islands off Norway. In recent years the reproductive success of these birds has declined dramatically, reaching zero in some years, apparently due to competition from industrial fisheries for sprats *Clupea sprattus* and sand eels *Ammodytes spp.* The adult birds seem to be in reasonable health, but they are unable to find sufficient fish of the right size to feed their chicks. Obviously this is a serious situation but where should they lie on our scale?

A brief sketch of the relevant details shows an entirely different set of circumstances to be accounted for, compared with the blue whale. For this population, current levels of abundance are comparable with historic levels and the species is not exploited. There is no evidence of increased adult mortality, but this could not be ruled out. The birds reach sexual maturity at 4-5 years of age and live 25-30 years. Nesting habitat is not under threat.

Given these parameters, this population could be extinct in about 20 years time. Now we must decide what time scale might be required for suitable conservation measures to have an effect. Given the structural problems in North Atlantic fisheries it does not seem unduly pessimistic to suppose it might take five years to complete the institutional stage of conservation measures, which in this case could be a prohibition or reduction of fishing in a zone around the islands. To this we would add a time for the recovery of the fish stocks which could be about five years also. Thus it would be about ten years before we would expect to observe any effects of conservation warnings issued now. Monitoring would not be difficult because it is easy to observe the birds' breeding success; a couple of good broods would be evidence that effective conservation had been achieved.

Thus, under our earlier conceptual classes we would conclude that this population should be classed as 'threatened'. However, if no conservation action were contemplated in the next five years, the population would have to be reclassified as endangered.

This example reveals a potential danger with classifications of the form 'threatened'. Such a classification could be interpreted that conservation action has not yet become necessary and that no action need be taken until a species is classed as 'endangered'. Such an interpretation would defeat the object of the classification, which is to suggest that modest conservation measures are necessary now. This is preferable to heroic measures at a later time.

Harp Seals in the North West-Atlantic

How would we expect the controversial status of this population to fare under the scoring system? The brief facts are: harp seals are still relatively abundant: a range of estimates suggest that the current population is of the order of 1-2m. animals. The population is considerably smaller than it once was, somewhere in the range of 25 to 50 per cent of pristine abundance. The rate of exploitation is high and it is uncertain whether the current levels of harvest are sustainable. The population could be increasing, but it could still be declining. The management regime is optimistic in the sense that catch quotas are based on 'best' estimates and make little allowance for the high levels of uncertainty. Different methods of estimation have been tried and do not give consistent results, and the precision of these estimates is not sufficient to be able to detect positively any trends in population size until a significant change has occurred or a series of estimates have been obtained over a considerable time. The government under whose jurisdiction these animals are harvested is unconvinced of the need for any reduction in the level of exploitation. The habitat is affected by intense commercial fisheries which may reduce their food supply and also lead to increased mortality from entanglement in fishing gear.

The levels of uncertainty, the high rate of exploitation and the insensitivity of the monitoring methods should together indicate that this is a 'threatened' population. It is not likely to be driven to biological extinction within the immediate future but there is a likelihood that under the current catches it will continue to decline. It is already depleted and it would not seem appropriate for it to decline any lower. Thus, it merits a classification to indicate that some conservation action should be implemented and monitoring activity be intensified if a pup kill is to be continued.

Hooded Seals in the North-West Atlantic

A population of this species is exploited along with the harp seals. The salient facts are similar to those for the harp seal, except that the hooded seal is considerably less abundant and the levels of uncertainty very much higher. The species is more vulnerable than the harp seal because the value of its skin is much greater, and so long as there is a harp seal hunt, it is profitable to take hooded seal pups regardless of how scarce they may be. The question of the hooded seal's classification devolves on the effectivenss of management. It would certainly merit a 'threatened' classification and quite probably, 'endangered', because the current methods of monitoring are such that a decline may not be detected before the population reaches levels so low that conservation action may not be initiated before its state becomes critical.

North Sea Herring

This population is an example of the problems that a dynamic and abundant species represents for a scheme of classification. Briefly, this herring stock declined from a biomass of around 2,000,000 tonnes in the 1950s to less than 200,000 tonnes by 1976. The accepted reason for this dramatic decline is over-fishing, to the point where recruitment was severely affected. Catches peaked in 1965 and thereafter declined steadily despite continuing improvements in catching efficiency. By 1970 fisheries scientists were becoming concerned. Some catch restrictions introduced in the early 1970s were ineffective in reducing fishing mortality. Not until 1976 was catching finally prohibited, by which time the stock was severely depleted. However, by 1980 the biomass of the stock had increased to around 300,000 tonnes, though the increases appear to be marked in some sub-areas and not to have occurred in others.

How should this population have been classified at some points in its history? By 1970, given the declining catches and the lack of management regulation, the population should have been classed as 'threatened'. Only a few years later an 'endangered' classification would have been justified, because, even though by 1974 catch limits were being set, these were greater than the quantities that could actually be caught, indicating that conservation action was lagging behind the decline in stock size, and hence the time-scale for conservation action was no longer than the time to effectively extirpate the stock. By 1981 there was some evidence that the population was increasing and, under our scheme it would not be long before it would be reclassified as 'threatened'. Assuming an adequate management scheme, it should not take many years before the biomass would be at a level where the classification of 'unendangered' would apply. This is because this species is a dynamic one, and some latitude would be allowed in determining the level of abundance which would be regarded as comparable with historic levels.

One point from this example is that the pace of events moves quickly for a dynamic species, and the application of a classification scheme may prove burdensome. There is a danger of a classification rapidly becoming out of date, and this would be dangerous for the credibility for the classification scheme itself.

Conclusion

The threats to the survival of species are so diverse that they defy a method of classification based on simple definitions; the number of factors to be considered make any comprehensive definitions too cumbersome. The solution proposed in this discussion is to recognise this diversity and analyse the status of a species with respect to every possible source of threat in a systematic way. This would not only have the advantage of improving the consistency of classification, but it would offer a succinct summary of our knowledge of the classified species. From this information we can assign a class that is supported by as full an analysis as is feasible. The properties of such a scheme and the definitions of classes would thus have a formal structure which would generate more uniform understanding and interpretation.

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